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Saving Energy in Nantucket Public Schools

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Abstract

The goal of our project was to analyze how the Nantucket Public Schools use energy and to make recommendations on how to reduce energy consumption. To address this goal, we performed a detailed technical and behavioral energy audit of the school buildings, which consisted of field data collection, analysis of past energy bills, distributing surveys, observing classrooms, and conducting interviews with teachers. Using the information gathered from the energy audits we offered the Nantucket Public Schools recommendations on how to reduce energy consumption. Additionally, we created a website containing energy facts and conservation tips to serve as an educational resource to the students and faculty of Nantucket Public Schools, as well as the community of Nantucket.

Executive Summary

Nantucket is an island 30 miles off the coast of Massachusetts and experiences even higher energy rates than the New England mainland due to the cost of transporting energy to the island. Nearly all of Nantucket's electricity is transported through two underwater cables that connect from Harwich and Hyannis, Massachusetts. Residents of Nantucket have to pay an additional surcharge for electricity to cover the costs of these cables. Unfortunately, the increasing population of Nantucket and seasonal tourism on the island has dramatically increased the demand for electricity. To forestall the installation of a third cable and meet the increasing demand, Nantucket has embarked on efforts to reduce energy consumption and corresponding costs of energy.

The Nantucket Public Schools account for about 16% percent of the town's municipal energy consumption. Though the total amount of energy consumed by Nantucket Public Schools is known, the details of how it is being consumed is not well known. The breakdown of where energy is being consumed and how it is being consumed can be determined by performing an energy audit on the schools.

The purpose of this project was to aid the Nantucket Public Schools in decreasing energy consumption within school buildings. This was accomplished by providing the schools' administration with a detailed assessment of energy consumption patterns in each school building. The analysis consisted of a technical assessment to determine how much energy was being consumed by appliances and electrical devices as well as a behavioral assessment, that identified the practical uses of energy and how energy was being consumed in the school buildings.

Additionally, an educational resource for energy conservation and energy consumption awareness was developed for both the students and faculty of the Nantucket Public Schools. The resource was created using the information gathered from the technical and behavioral assessments and provides users with information regarding energy, how energy is consumed in Nantucket, how energy is consumed in Nantucket Public Schools, and energy conservation strategies.

As part of our energy audit of the Nantucket Public Schools, we assessed every room for thermal inefficiency and improvements in reducing energy consumption. We most frequently used the Forward Looking Infrared camera (FLIR) to find changes in temperature identifying heat leaks within the buildings. We also used the FLIR on the rooftops of each building. Although our initial goal was to identify leaks within the rooftop infrastructure, we later found that doors, windows, and walls were a much greater issue.

The behavioral assessment consisted of staff surveys and classroom observations. To help us gain a better understanding of energy use in Nantucket Public Schools we administered two different surveys to the staff of all four schools. The first survey asked a series of demographic questions to determine the sample size of each school and was designed to assess the existing energy conservation knowledge of the staff members. The second survey was intended to provide us with more statistical data regarding energy use in the schools. The second survey also asked questions about personal appliances and electronic devices, energy educational resources, and the efficiency of the schools' HVAC systems.

Our team observed 13 classes at Nantucket Public Schools. Each class observation typically lasted two hours and had 1-3 team members observing. Throughout the duration of class time, each observer would complete an observation sheet, which asked the observer to elaborate on different aspects of energy use in the classroom, such as heating, lighting and electricity use.

After applying our methods to the Nantucket Public Schools, we obtained results that have helped us determine ways for Nantucket Public Schools to reduce energy consumption. Additionally, we have created educational resources regarding energy awareness and conservation for the students and staff of the Nantucket Public Schools as well as the general public.

Overall, there are both behavioral and technical improvements that Nantucket Public Schools can implement to conserve energy. As a team, we have come to three conclusions: most of the staff at Nantucket Public Schools is adequately aware of energy conservation and consumption at the schools, numerous opportunities exist for energy awareness improvements within the schools to conserve energy, and energy is wasted by old appliances and electrical devices.

First, to educate the staff on energy awareness we created an educational website that contains energy facts that are linked to QR codes. These QR codes are displayed on energy conservation posters posted on the walls at the schools. We also recommend that the school create an energy club that could help manage and maintain this website. Another recommendation is for the schools to integrate energy educational resources into the curriculum. Special websites such as need.org, Energy Information Administration: Energy for Kids, and the National Grid Energy Explorer all have certified curricula ranging from simple calculations to student home audit projects to help reduce energy consumption.

Second, to improve energy conservation in the schools, we recommend that the administration consider installing energy efficient windows and weather stripping, re-evaluate the placement of certain lights in hallways, improve HVAC systems, as well as inspect the Elementary school outer walls for insulation. We also suggest that the schools utilize blackout shades in rooms that are seasonally affected by wind turbine flickering.

Third, from our inventory we discovered many personal appliances such as miniature refrigerators, microwaves, lamps and printers. We totaled all of the devices discovered in the four public schools and created a comprehensive inventory of each school. From our inventory and data collection we created an excel sheet which includes the approximate energy consumption of all appliances and devices per week as well as the typical hours the device is used per week. From these readings we were able to develop a cost benefit analysis to determine where the schools can save energy. By removing personal appliances from where they are not necessary, energy consumption within the schools can be reduced. These appliances can be sold or traded in through a recycling program for rebates to assist in the payments of energy efficient appliances.

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1.0 Introduction

As the world's economy and population rise over time, the demand for one resource raises as well, energy. In 2010, the world consumed 524 quadrillion Btu's of energy (Energy Information Administration, 2013). It is projected that in the year 2020, the United States alone will consume 100.5 quadrillion Btu's of energy (Energy Information Administration, 2013). Not only does the rise in demand for energy have environmental impacts due to an increase in Greenhouse Gas (GHG) emissions into the atmosphere, but it forms an economic issue as well. The rise in demand for energy causes increased energy rates due to limited availability of accessible resources.

The United States places second only to China as one of the world's top energy consuming countries. According to the U.S Energy Information Administration, the average cost for electricity in the U.S. amongst the four sectors, (residential, commercial, industrial and transportation) increased from 10.31 cents per kWh in September of 2012, to 10.45 cents per kWh in September of 2013. Although this increase is small, there are regions of the country which experienced more significant growth in the cost of electrical energy. Over the same time period, the New England region increased from 14.2 cents per kWh to 15.1 cents per kWh (Energy Information Administration, 2013). In 2010, the U.S. Census reported a population of roughly 14,000,000 people, roughly 4,500,000 households in the New England area (Rhode Island Department of Labor and Training, 2010). An average New England household uses about 640 kWh of electricity per month (Energy Information Administration, 2013), resulting in a total of 2,880,000,000 KWh of electricity consumed per month by households in New England. The 1 cent increase in price per kWh is a $28,800,000 per month increase in electrical energy cost in New England alone.

Nantucket is an island 30 miles off the coast of Massachusetts and experiences even higher energy rates than the New England mainland due to the cost of transporting energy. Nearly all of Nantucket's electricity is transported through two underwater cables that connect from Harwich and Hyannis, Massachusetts. Residents of Nantucket have to pay an additional surcharge for electricity to cover the costs of these cables.

Unfortunately, the increasing population of Nantucket and seasonal tourism on the island has dramatically increased the demand for electricity. To forestall the installation of a third cable and meet the increasing demand, Nantucket has embarked on efforts to reduce energy consumption and corresponding costs of energy. One of the efforts Nantucket has made has been the installation of a wind turbine as an alternative source of energy. The turbine is directly connected to Nantucket High School and from September of 2012 to September of 2013, has given the Nantucket Public Schools approximately $12,000 in renewable energy credits and has helped avoid $24,980 in electricity cost (Town of Nantucket Eneryg Office, 2013). This has saved the school a total of $37,055 in the past year.

The Nantucket Public Schools consume about 16% percent of the town's energy (Town of Nantucket Eneryg Office, 2013). In 2011 an Interactive Qualifying Project (IQP) was completed by WPI students who conducted an analysis of total energy consumption within the Nantucket Public Schools. In January of 2013, the schools had a complete lighting audit done by Northern Energy Services in compliance with National Grid's Energy Initiative Program. The proposal to replace all lights in the facilities has since been adopted and is currently underway. The lighting replacement has a calculated payback period of 3 years and is then projected to save the Nantucket Public Schools $20,000 per year (Northern Energy Services, 2013). Although the total amount of energy consumed by Nantucket Public Schools is known, the details of how it is being consumed is not well known and continuing to finance major upgrades would involve significant planning and money. Therefore, energy saving measures are needed to provide the time required to form a budget for major upgrades.

The breakdown of where energy is being consumed and how it is being consumed can be determined by performing an energy audit on the schools. Audits are used to identify areas where improvements in energy efficiency can be made**.** Energy audits can be divided into two parts: a technical assessment and a behavioral assessment. The technical assessment is used to track where energy is being consumed and where reductions are possible. The behavioral assessment is used to determine how conscious students and faculty are about energy consumption and what steps are already being taken to conserve energy. From these assessments, an educational training program can be developed for the students and faculty of Nantucket Public Schools to increase energy conservation awareness and decrease overall energy consumption within the schools. It is likely that the ideology of energy conservation will then become more prevalent throughout the island.

Our assessment of Nantucket Public School's energy usage offers the faculty and administration of Nantucket Public Schools a better understanding of where energy is being consumed specifically throughout their buildings and suggests future energy conservation strategies.

2.0 Literature Review

The Literature Review section is intended to provide the reader with the necessary background information needed to understand the goals and objectives of this project. This section will present an analysis of previously existing research and data to provide historical, technical, sociological, political and economical insight to our project. This Literature Review section will specifically discuss the topics of energy consumption on a global and regional scale, energy consumption in the Nantucket Public Schools, and how to perform energy audits.

2.1 Energy

Energy, in the simplest description, is the capacity to do work (Merriam-Webster Dictionary). With the worldwide demand for energy increasing and the available sources of energy decreasing, it is essential to develop means to conserve energy.

2.1.1 Energy Sources

Energy sources are classified into two distinct categories: renewable and nonrenewable. Examples of nonrenewable sources are oil, gas, coal, and nuclear energy. Some renewable energy sources are solar, wind, geothermal, and water. Renewable and nonrenewable energy sources are known as primary sources of energy, meaning that they create energy directly from a resource.

Primary sources of energy can be converted into secondary sources (also known as energy carriers) in order to transport energy in more stable forms (Engineers, 2006). The most commonly used secondary source of energy is electricity. Another secondary source of energy is Hydrogen. Although hydrogen is not currently used as widely as electricity, it has potential to become a dominant energy carrier in the future because hydrogen is produced from a wide variety of resources and is a common byproduct in chemical processes (Energy Information Adminisitration, 2013). More examples of primary and secondary energy sources are shown below in Figure 1.

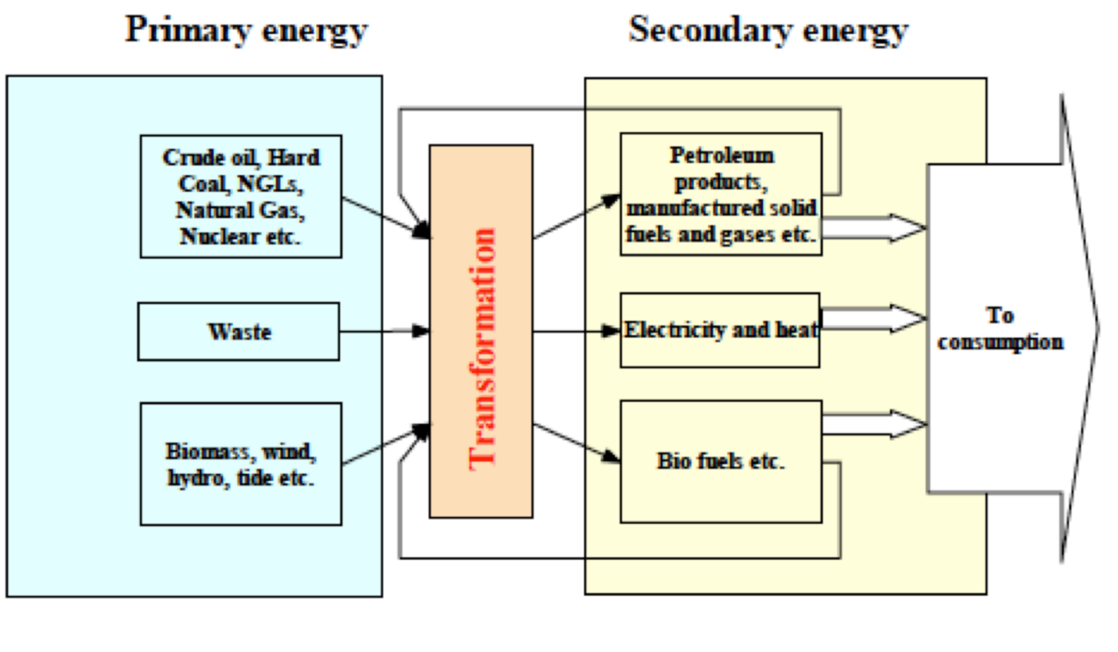

Figure 1: A Diagram of Primary and Second Energy (Overgaard, 2008)

2.1.2 Electricity

Electricity can be classified as both a primary and secondary source of energy. According to both the UN and the OECD/IEA/Eurostat manuals, electricity is classified as a primary source when generated directly from a natural resource such as wind or solar energy. It is classified as a secondary source of energy when it is generated from the steam of a primary source, such as coal, gas, oil combustion, or nuclear fission. Although electricity is classified as both a primary and secondary source of energy, it is more often simply defined as a secondary energy commodity by the UN and OECD/IEA/Eurostat manuals (Overgaard).

2.1.3 Energy Uses

In 2009, electric power accounted for 41% of the United States' total energy consumption (Energy Information Administration, 2013). The unit of measurement for energy in the United States is watts and the unit used to measure energy over time is kilowatt-hours. Appliances come with power ratings indicating the maximum power that the appliance is capable of using. The maximum power is reached when the appliance is using the peak amount of electric power. For instance, a standard radio's volume is controlled by a dial. When a radio is playing at maximum volume, it is using its peak amount of electric power, which corresponds to the value provided by the power rating of the appliance. However, for any other volume level, a Watt-Meter would be needed to determine the actual electric power being used. A television has an average power rating of 130 watts, whereas a refrigerator has an average rating of 725 watts and a 40-gallon water heater has an average rating of 4500 watts (Mclean, 2013). Although the television has a lower maximum power rating than a water heater, the television stays at its maximum power rating for longer periods of time. A water heater might only turn on a few times a day to maintain water temperature. This means that the two appliances may actually be using the same total energy which is why it is important to consider how long an energy consuming device is on.

2.1.4 Phantom Loads

An effective way to conserve energy is to eliminate or reduce the number of "Phantom Loads" in a building. A phantom load, also known as standby power or "vampire power", can be defined as the energy consumed by an electrical device while powered down, but still plugged into an electricity source. This electricity consumption can often go unnoticed as the device is turned off and the owner of the device may not be aware that it is still using electricity. Although devices in standby mode draw small amounts of energy, over time these phantom loads can add significant costs to an energy bill.

Almost all appliances use some level of electricity when they are turned off. For example, about 95% of United States households have a microwave (deLaski, 2013). The national residential average cost for electricity is 12.51 cents per kWh (Energy Information Adminisitration, 2013). Applying this average rate to the standard microwave's annual electricity consumption estimates a total cost of $4.38 per year. This is the price that a consumer pays over the course of the year for an unused microwave, a relatively efficient appliance. Table 1 compares typical electric devices found in an office and how much standby power they are using.

Common Appliance	Avg. Phantom Load[i]	Annual Cost[ii]
Laptop Computer	8.9 W	$8.97
Desktop Computer	2.84 W	$2.86
Computer Display (CRT)	0.8 W	$0.81
Speakers, computer	1.79 W	$1.80
Modem, cable	3.84 W	$3.87
Printer - inkjet	1.26 W	$1.27
Copier	1.49 W	$1.50
Fax - inkjet	5.31 W	$5.35
Scanner	2.48 W	$2.50
Surge Protector	1.05 W	$1.06
Phone - cordless with answering machine	2.92 W	$2.94

Table 1: Phantom Loads of Common Appliances (Delaski, 2011)

The electricity being consumed through phantom loads by the appliances in Table 1 combine for a total estimated cost of $32.93 per year. One way to reduce phantom loads would be to utilize a modern power strip with a cut-off auto sensing circuit. If several appliances are plugged into the protector and not being used, then the circuit can sense the phantom loads and turn all of the devices plugged into the power strip off eliminating phantom loads from all of the connected devices. Another way to eliminate phantom loads of course would be to simply unplug electronics when not in use.

2.2 Global Perspective of Energy Consumption

Over the 30 year period from 2010 to 2040 the world's total annual energy consumption is projected to rise by 56 percent from 524 quadrillion Btus to 820 quadrillion Btus (Energy Information Administration, 2013). This increase in energy consumption has been linked to the rapid economic growth of many countries, such as China and India. Of the projected increase in global energy demand, 85% of the increased energy consumption can be attributed to nations outside of the Organization of Economic Cooperation and Development (OECD), who have increasing populations and growing economies. Three countries that fall into this classification are the three largest energy consuming countries in the world, the United States, China and India. Figure 2 displays past, current and projected future trends in energy consumption by the world's three highest energy consuming countries. All trends in the data show an increase in energy consumption for each country. According to Figure 2, in 2010 the United States and China were tied as the leading energy consuming countries. In the year 2040, China is projected to consume twice the amount of energy as the United States (Energy Information Administration, 2013).

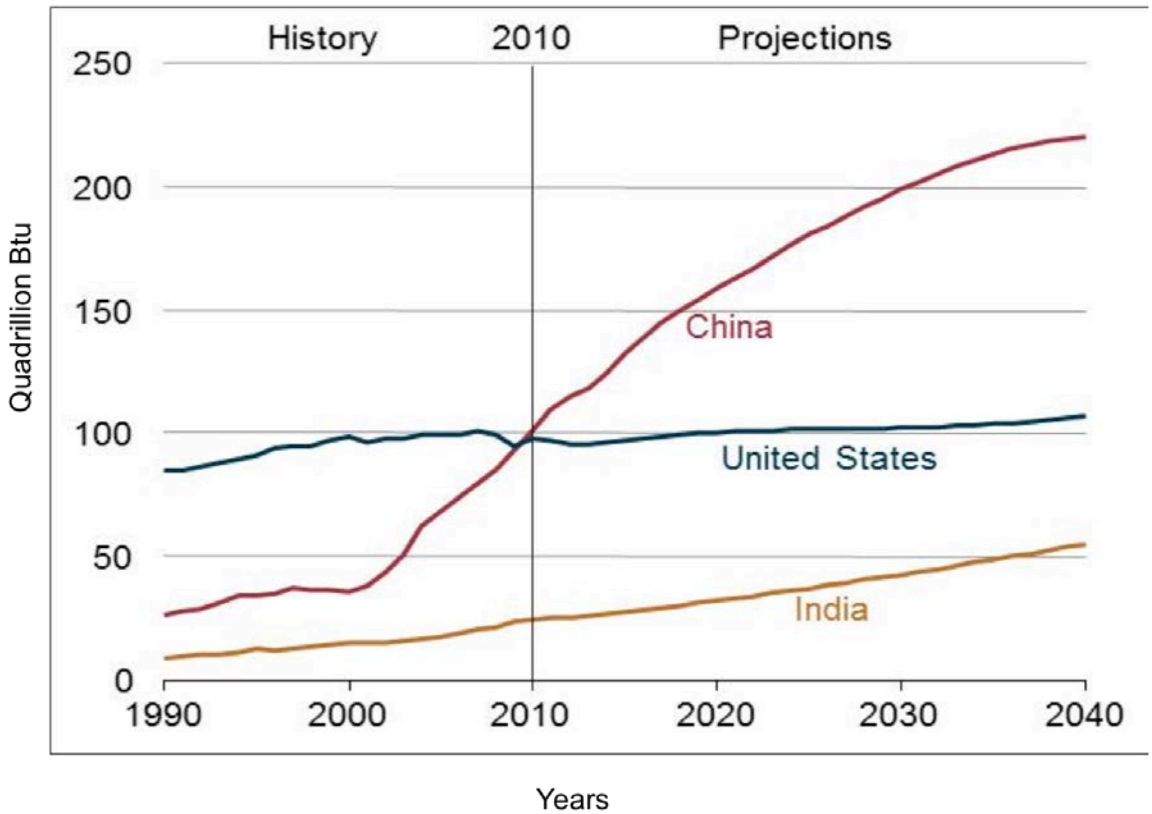

Figure 2: Total Lead World Consumption Projections (EIA, 2013)

2.3 Energy Consumption in the United States

In 2011, the United States ranked second only to China as the world's largest consumer of energy, consuming 4,138 billion kWh of electricity (Energy Information Administration, 2013). Figure 3 shows data from the World Bank that reflects the increase in demand of electricity, showing a rise in consumption from 4050 kWh per capita per year in 1960 to 13000 kWh per capita per year in 2010, accounting for a 320% increase in electricity consumption over the 50 year time span (Department of Energy). The total annual consumption of electricity in the United States has increased by an average of approximately 10,000 kWh per capita per year over the past 50 years.

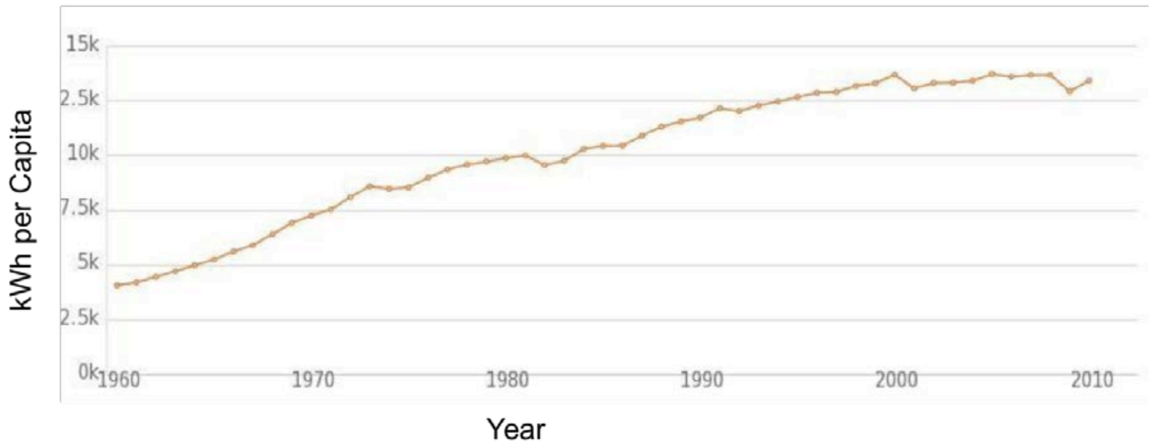

Figure 3: Electrical Power Consumption per Capita in US (World Bank, 2012)

2.3.1 Short Term Electricity Outlook

Along with a rise in consumption in electrical energy, there has also been an increase in cost of electricity in the United States. According to the EIA Short Term Outlook graph, Figure 4, the cost of electricity for the average residential rate in the United States has experienced a 56% increase from 8 cents per kWh in 2001 to the current 12.5 cents per kWh in 2013. Additionally, the demand of electricity in the United States is projected to grow 28% between the years 2011 and 2040 (Energy Information Administration, 2013). The graph also shows that annual peaks in price occurs midyear during the summer months, signifying that electricity generally costs more in the summer, rather than the winter. Since it has been determined that both the rate that the United States consumes electricity and the rate in cost for electricity are both increasing, it can be concluded that the total dollars spent on electricity in the United States will also increase.

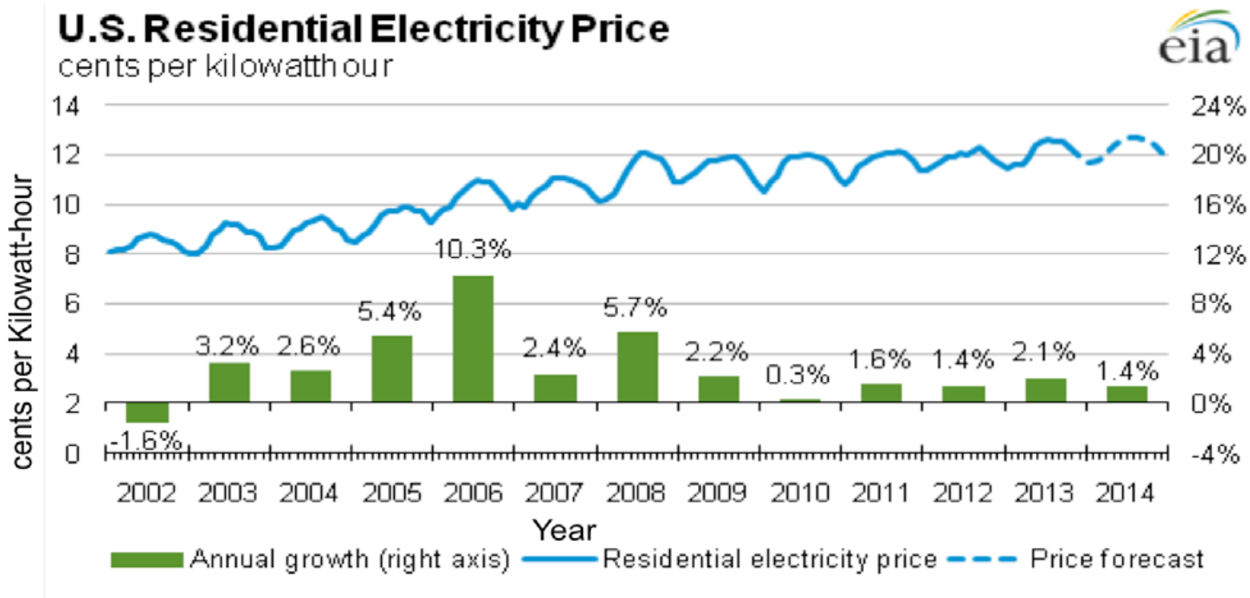

Figure 4: Short Term Electricity Outlook (EIA, November 2013)

With a rise in demand for power and electricity, some of the energy transmission electrical grids will not be able to accommodate the increasing demand. The inability of the grid to meet the rising demand is already evident in the brownouts and blackouts that have become more frequent over time (Dade, 2012). A brownout is a period when the electrical voltage in an area is reduced because there is a reduction in the electrical power that can be supplied to the consumers in the area served by the transmission grid or power generators (Merriam-Webster Dictionary).

2.3.2 Residential Energy Usage (Way)

A breakdown of the distribution of annual energy consumption in a typical United States household according to the Energy Information Administration is shown below in Figure 5. The breakdown displays different ways that energy is consumed in residences such as heating, cooling, appliances and lighting. An average household energy bill is about $2200 per year. Of this total, heating accounts for about 30% of the energy bill (Energy Information Administration, 2013)

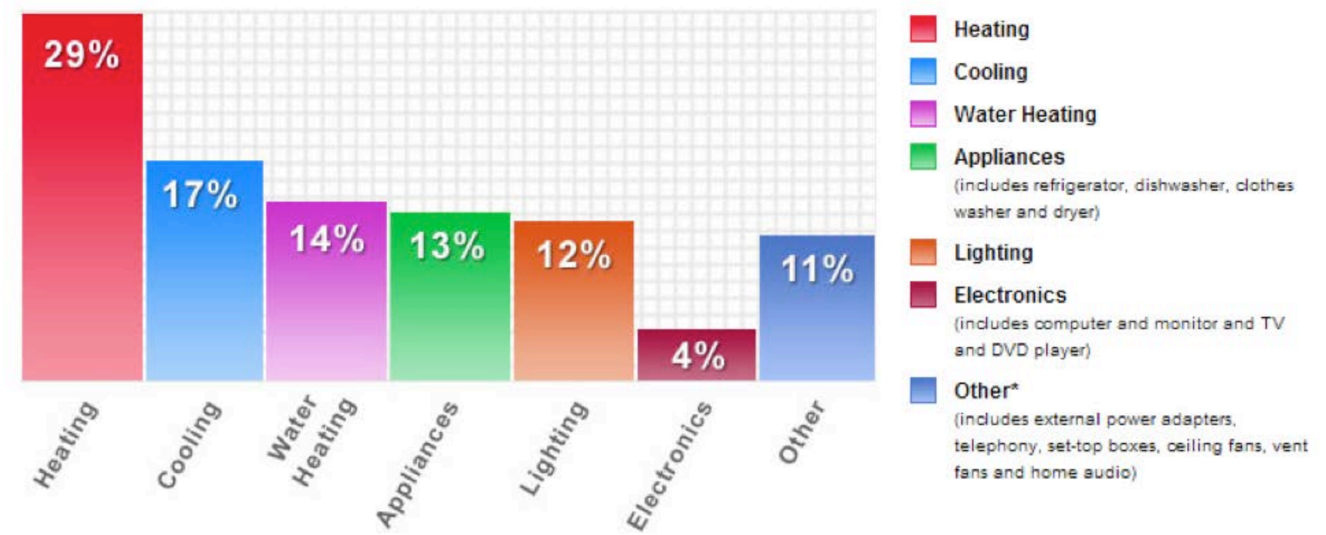

Figure 5: Annual Energy Consumption in a Typical Household (EIA, 2013)

2.3.3 Government Policies to Reduce Energy Consumption

In an effort to reduce the amount of electricity used in the United States, the US government has ratified rules and regulations regarding energy use. For example, the Energy Policy Act of 2005 states that all federal buildings must have various energy-reading meters and conduct energy reports daily so that buildings can use electricity more efficiently and overall consumption can be reduced. (Enviromental Protection Agency, 2012)

The Energy Independence and Security Act (EISA) of 2007, requires federal companies and agencies to reduce the amount of energy consumed by 30% by the year 2015. This act also pushes new commercial buildings to have a zero net energy goal by 2025 and existing buildings by 2050. Details of the act include a clause stating that 30% of the hot water supply must be obtained from a renewable energy source (Enviromental Protection Agency, 2012).

2.4 Energy Consumption on Nantucket

Nantucket is an island off the coast of Massachusetts and has one of the highest rates of electricity in all of New England. In the United States, the average residential rate for electricity is between 10 and 12 cents per kWh. On the island of Nantucket, the residential rate for electricity is 18.4 cents per kWh (Energy Information Adminisitration, 2013). On top of this electricity rate, all residents of Nantucket pay an additional surcharge, which goes toward the payment for the installation of two underwater cables.

2.4.1 Sources of Energy on Nantucket

The majority of electrical energy used on Nantucket is generated by natural gas within the state of Massachusetts as shown in the Figure 6 (Energy Information Adminisitration, 2013). A power plant generates electricity for the island and is then transported by two undersea cables. The first of the cables was installed in 1996. It was installed as a replacement to the town's old power plant**,** which could no longer provide sufficient power for the entire island. The cable has a 38 MW capacity and connects from Harwich, Massachusetts to Nantucket. In 2006, the second 36-megawatt cable was installed, connecting from Hyannis, Massachusetts (Town of Nantucket Eneryg Office, 2013). Electricity is also supplied through one public and one private wind turbine. The combination of the cables and wind turbines produces enough energy to supply the average 13,000,000 kWh needed per month on Nantucket.

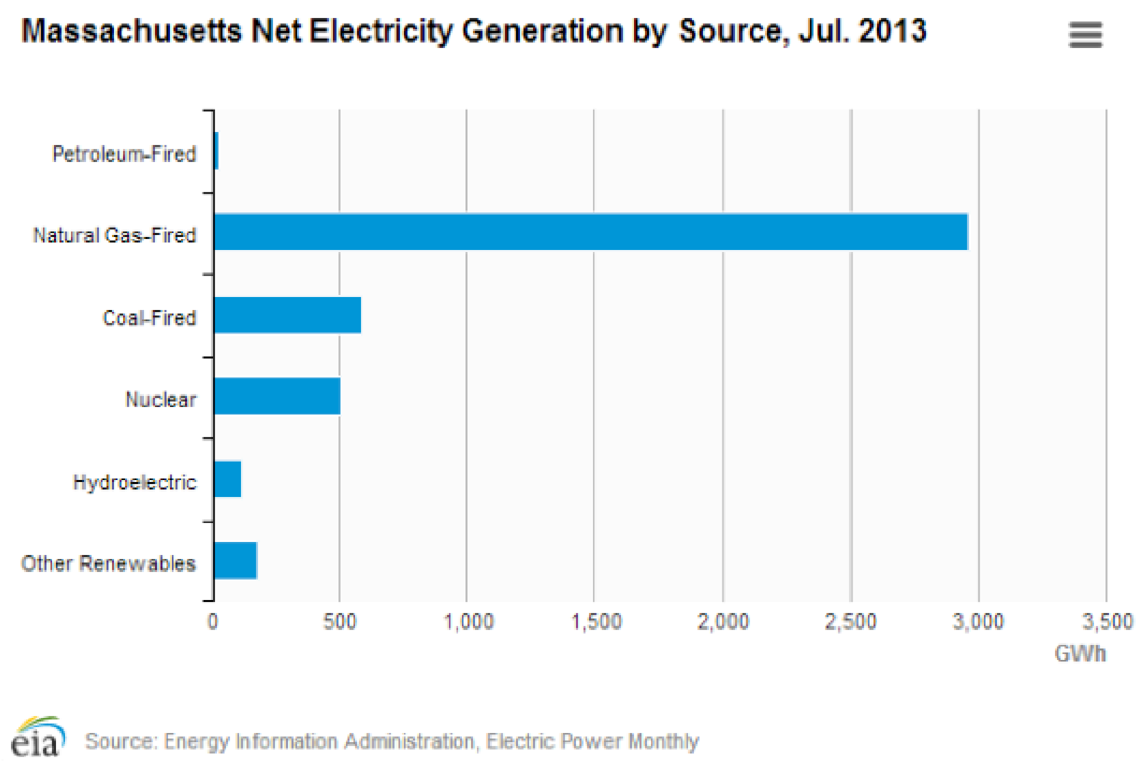

Figure 6: Massachusetts Net Electricity Generation (EIA, 2013)

Although on a typical day on the island, the two existing cables are more than capable of supplying the electricity demand, the annual peak load for the cables has been increasing. Figure 7 displays the maximum electricity load experienced from 2008 to 2013. It also shows projections for future peak loads up to the year 2023. The green horizontal line represents the maximum capacity of one cable and the on-island backup generator. In the year 2013 the peak electricity load on Nantucket nearly reached the capacity of one cable, posing the idea of a potential need for the installation of a third question. Although the current peak load can be supported by the existing cables, future projections, which take into account conservation initiatives, show an increasing trend in peak loads. According to the figure, in the year 2023, the peak load on Nantucket will be just under 60 MW which, some would argue, is critically close to the capacity of the two cables.[1] Because of this, Nantucket as a community must begin to consider the possible installation of a third cable for the future.

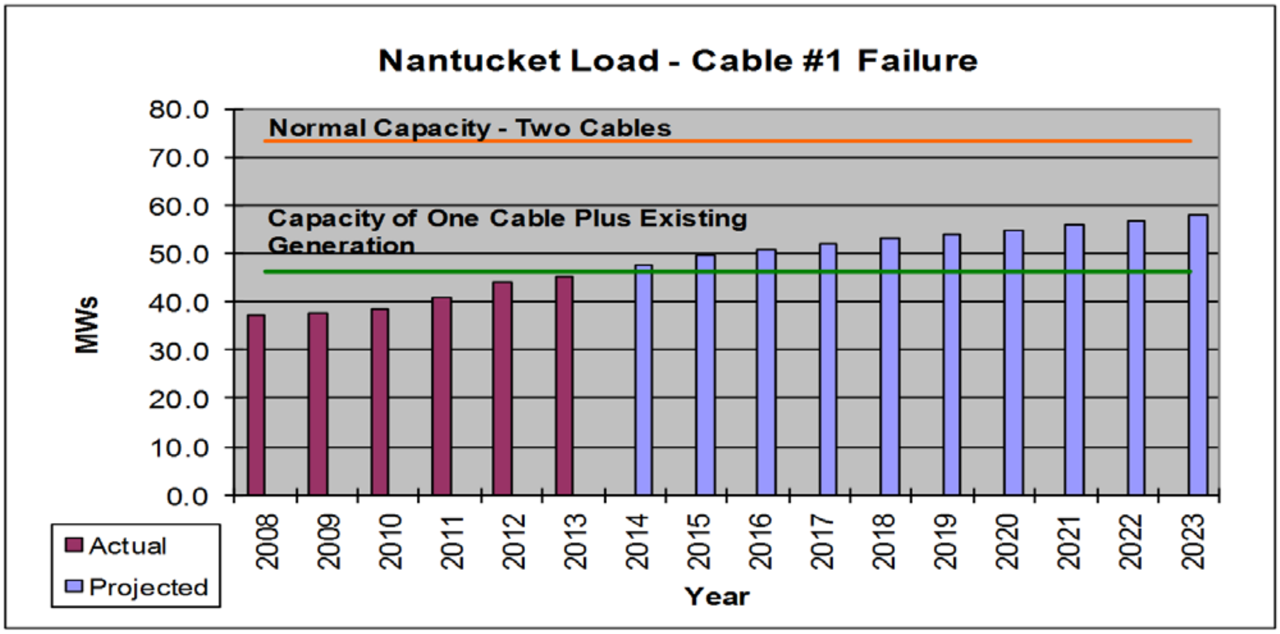

Figure 7: Annual Peak Load of Electricity Generated by Cables

2.4.2 Energy Use in Nantucket

Nantucket is a well-known tourist attraction; it is a prime vacation destination for many families during the summer months. It has a year-round population of 10,000-12,000 people, but during the summer months, it has an approximate population of 50,000-60,000 people (Nantucket Basic Facts, 2013). Naturally, with such a dramatic increase in population comes an increased use in electricity, which corresponds to the peaks of electricity usage in Figure 8. The graph is used as a timeline that shows the differences in electricity usage in each season from 2001 to 2011. Each year, the peak of electricity use on the island is between 12,000,000 and 17,000,000 kWh per month. The increase in population only raises total electricity use by twice as much and is primarily due to the fact that the residential sector does not consume all the energy on Nantucket. Public and private buildings are responsible for 40 percent of total electricity consumption (Department of Energy).

[1] The information provided from Figure 7 is from a presentation provided through National Grid

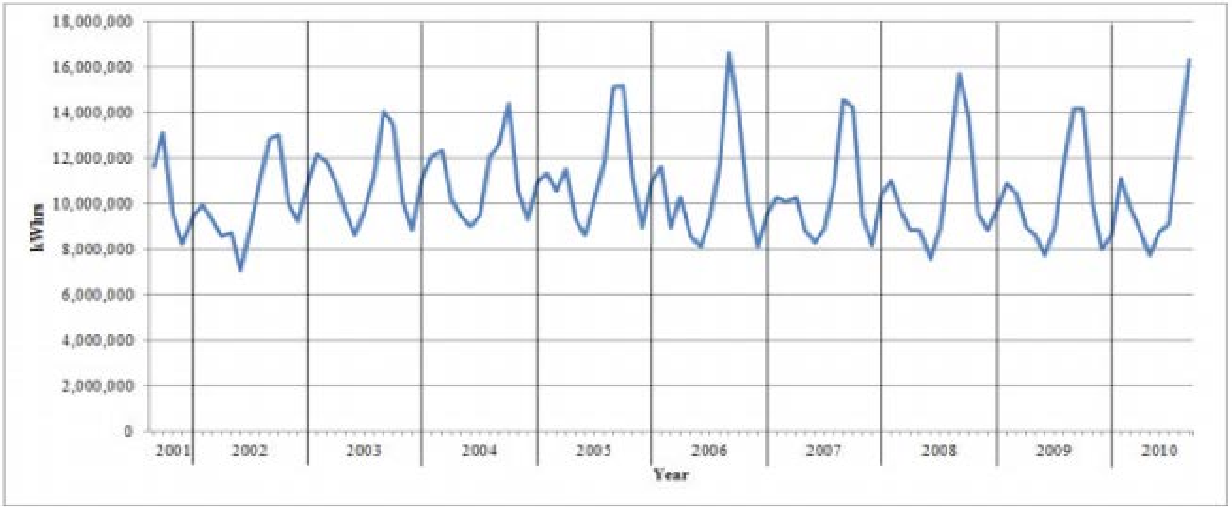

Figure 8: History of Electricity Use in Nantucket (EEA Migration Reports, 2011)

2.4.3 Feasibility of Using Renewable Energy on Nantucket

There has been discussion on Nantucket as to whether or not to implement solar energy (Nantucket HDC, 2013). However, since Nantucket was declared a historical district in 1966 (Nantucket Basic Facts, 2013), the focus has been on keeping the island historically preserved. With the town's guidelines for historic land, restrictions have been placed that ban most solar panels from being on the ground (Nantucket HDC, 2013). These restrictions have led to placing solar panels on rooftops.

The practicality of solar panels on rooftops has building managers weary because of the naturally occurring high wind speeds on the island although research has shown that solar panels are designed to be able to withstand strong wind speeds and loads. Most manufacturers have designed their panels to withstand loads of 2400 Pascals and have also designed panels for high speeds around 120mph. It is difficult to directly correlate these forces to wind speeds because there are many factors to consider such as topography, height location etc. Therefore it is necessary to perform on site calculations to take all necessary factors of safety into the design (U.S. Department of Energy)

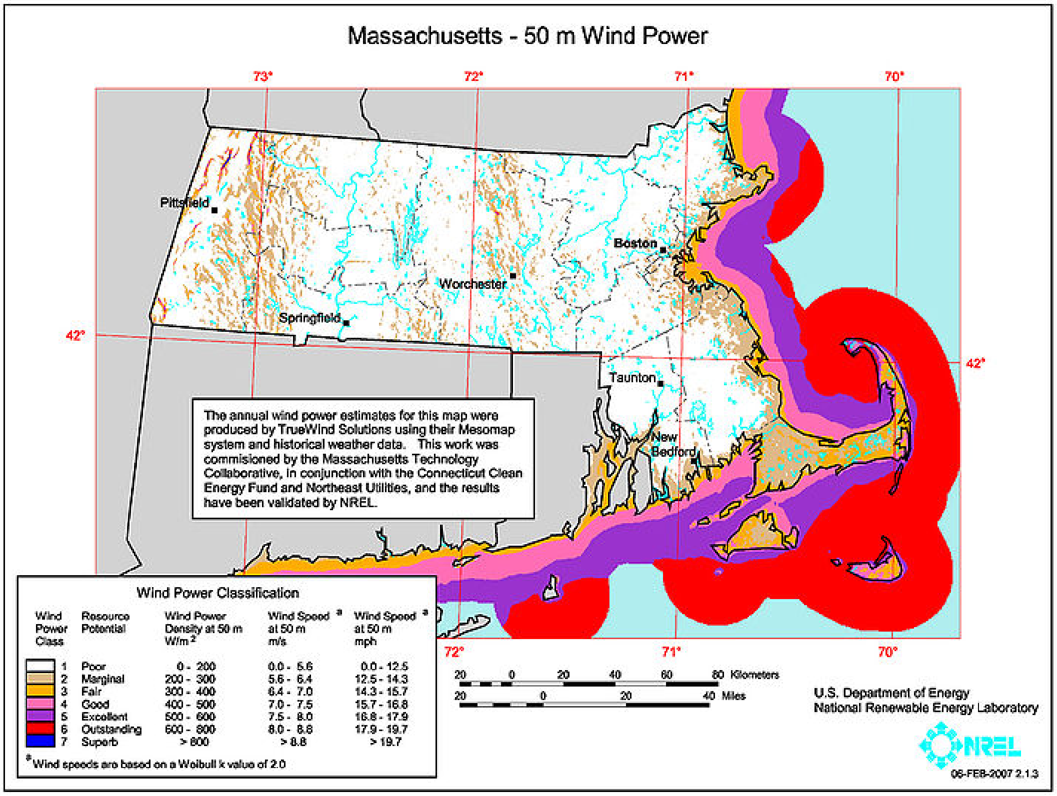

Figure 9: A Map of Wind Power on the Coast of Massachusetts (Wind Power, 2007)

Nantucket has never been short of wind, one of its most abundant natural resources, making wind energy an optimal source of renewable energy for Nantucket. Figure 9 is a map of the wind power classification surrounding the coast of Massachusetts. It shows that around the island of Nantucket, the wind power is classified between 5 and 6 which correspond to a wind speed of 12.8-19.7 mph at the altitude of 50 meters. Most wind turbines operate most efficiently at approximately 16 mph which means Nantucket is an ideal location to utilize wind power (Wind Powering America).

The wind turbines may be an innovative way to produce energy locally, but there remains the problem of where they can be located if additional wind turbines are to be considered. Being an island of only 47.8 square miles, there is limited open space to put the wind turbines that does not interfere with life on the island (Town of Nantucket Energy, 2013). Many residents oppose the construction of wind turbines as they find them to be disruptive and aesthetically displeasing. It was reported in the summer of 2013, that the privately owned wind turbine at Bartlett Farms was shut down temporarily when a portion of one of the blades had broken off (Save Our Seashore, 2013). Though it was properly maintained, it has concerned citizens of Nantucket regarding potential safety hazards of wind turbines. The commotion surrounding the wind turbine mishap has caused the town of Nantucket to reassess the future installation of new wind turbines to reduce energy consumption as a community.

2.5 Energy Consumption in Nantucket Public Schools

Public and private buildings are responsible for more than 40% of total energy consumption in the United States, which is more than the combined total of both the industry and transportation sectors (Department of Energy). In 2012, Nantucket municipal buildings consumed over 12,000 MWh of electricity, costing the town of Nantucket a total of 1.8 million dollars (Town of Nantucket Eneryg Office, 2013). Nantucket Public Schools was responsible for 16.4% of the town's total municipal energy consumption.

The Nantucket Public Schools consist of three separate buildings as shown in Figure 10. One building is the Nantucket Elementary School which consists of grades prek-5. Another much smaller building is the Nantucket Community School, which provides after school activities and adult education programs to the community of Nantucket. The third and largest building contains both Nantucket High School and Cyrus Middle School which contains grades 9-12 and 6-8 respectively. As of 2013, the Nantucket Public Schools have a total enrollment of 1,485 students (Nantucket Public Schools, 2013).

Figure 10: Google Earth Image of Nantucket Public Schools (Google, 2013)

2.5.1 Electricity Bills

The following numbers were calculated from the schools' monthly National Grid electricity bills over the course of a year, beginning on June 13th, 2012 and ending on June 13th, 2013. The Nantucket Public Schools have two monthly electricity bills: one for Nantucket Elementary School and one for the building containing both Nantucket High School and Cyrus Pierce Middle School. Both buildings pay a discounted base rate of 6.29 cents per kWh for electricity. However, both buildings also pay for several different service charges such as distribution and transmission charges. These charges can run as low as 0.05 cents per kWh for the energy efficiency charge to as high as 2.518 cents per kWh for the cable facility surcharge.

The most expensive additional service charge that Nantucket Public Schools pays for electricity is the cable facility surcharge. Powering the two school buildings over the course of one year cost the Nantucket Public Schools $39,791 just to cover the cost of the cable facility surcharge. This makes up 16% of Nantucket Public Schools' annual electricity bill of $246,015.

2.5.2 Utilizing Wind Energy to Reduce Electrical Costs

Nantucket High School now uses the newly installed Northwind 100 kW wind turbine, built in 2011 and shown below in Figure 11, to aid in reducing electrical costs (Town of Nantucket Energy, 2013). One of the benefits to using the wind turbine is that the energy is not imported to the island. Produced locally, the town saves money by not having to pay the expensive surcharge that comes with importing energy. The installation of the wind turbine has impacted the total cost of electricity for the Cyrus Pierce Middle School and Nantucket High School by saving the school $102.93 per day. In the year 2012, the wind turbine generated 210 MWh of electricity which has given the schools approximately $12,000 in renewable energy credits has helped avoid $24,980.55 in electricity costs (Town of Nantucket Energy, 2013).

Figure 11: Nantucket High School Wind Turbine (AckEnergy, 2013)

Figure 12 displays a timeline of electrical power generation per month produced by Nantucket High School's wind turbine since its installation. The overall trend of the graph shows a slight increase in electrical output over time. During the months of March 2013 to July 2013, there is a significant increase in electrical output. These five consecutive months all show an increase of about 5 MWh more than the same month in the previous year.

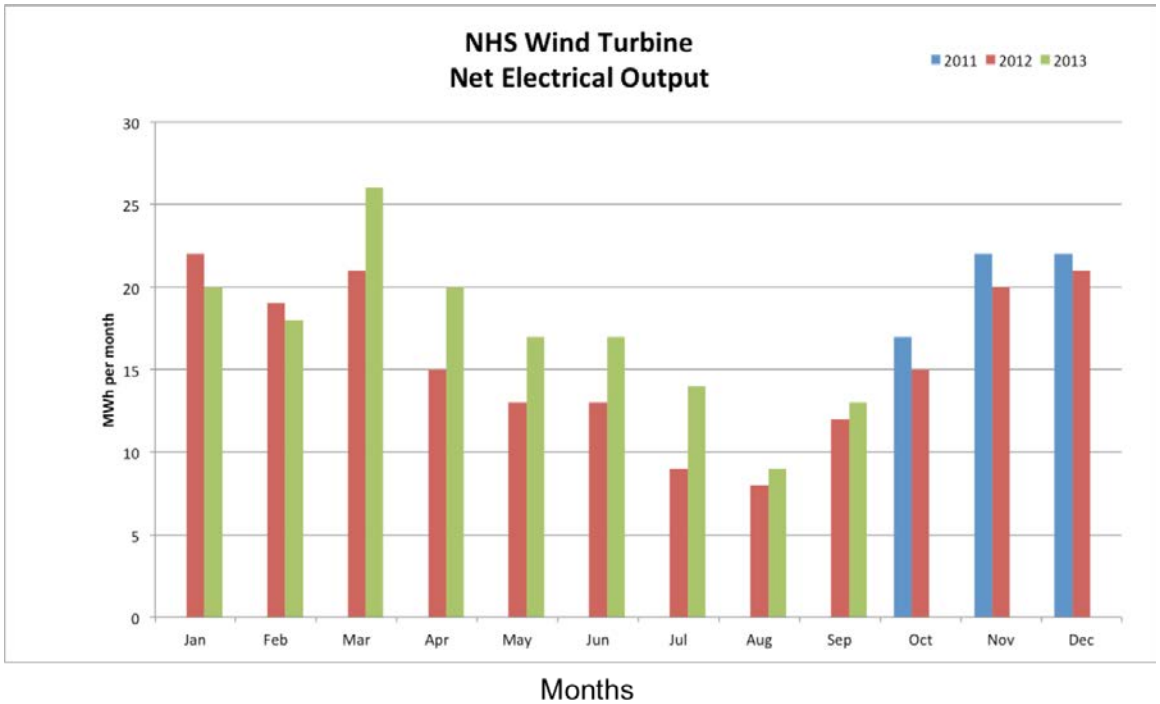

Figure 12: Net Electrical Output of NHS Wind Turbine (AckEnergy, 2013)

2.5.3 Lighting Audit

In December of 2012 Northern Energy Systems completed a full lighting audit of Nantucket Public Schools. Their proposal to replace all of the light bulbs in the Cyrus Pierce Middle School and Nantucket High School was implemented over the summer of 2013 and has an expected payback period of 3 years. The lighting audit is projected to save the schools $20,317 per year. Northern Energy System's proposal mainly focused on replacing old, fluorescent bulbs with new, more energy efficient LED or fluorescent (Northern Energy Services, 2013). These steps in energy conservation are just the beginning for Nantucket Public Schools. Northern Energy Systems is now proposing to follow up their lighting audit with a full electrical audit of the elementary, middle and high schools.

2.6 Energy Audit

An energy audit is the inspection and evaluation of a building's energy system. It is an effective tool that helps address the issue of where there is inefficiency. An energy audit can be broken down into two parts: a technical assessment and a behavioral assessment. The technical assessment will track where energy is being consumed and where implementing efficient solutions are possible. There are two different ways to conduct a technical audit: the checklist audit method and the visual audit method. The behavioral assessment is used to determine the existing knowledge and energy behavior practices of the energy users and what steps are already being taken to conserve energy. From these assessments, an educational training program can be developed for the energy users to increase energy conservation awareness and decrease overall energy consumption.

2.6.1 Technical Audit

A checklist audit is completed by using a detailed checklist to assess the energy use and efficiency of each room and appliance in a building or complex. Checklist audits, such as the Green School's initiative audit, provide a checklist for both high schools and elementary schools. The checklist audit provides a thorough list of all of the different aspects of the school that may need to be changed in order to conserve energy. This checklist focuses on types of energy sources, how much energy costs, and how stable the HVAC and lighting systems are within the schools. It also focuses on the current behaviors of students and faculty regarding energy and what steps they are already taking to reduce energy consumption. A checklist audit can be easily completed by the students and provides a hands-on approach to teaching them how to be conscious about energy consumption.

A visual audit is used to provide quantitative power use data that can be collected using a checklist audit. In a visual audit, the auditor goes through the building with specialized measuring tools to perform an analysis on the building's energy usage. The goal of the visual audit is to find leaks in the system, determine an accurate amount of energy used by appliances, and to identify the unnecessary use of electricity. By using tools to measure electricity use, the auditor is collecting more accurate data than would be collected by a simple checklist audit. This data can then be interpreted to see where electricity is being used and where it could be used more sparingly.

Conducting an energy audit is an effective way to determine whether or not a building is efficiently using energy. However, one cannot determine a completely reliable way to reduce energy consumption just by changing the appliances and electronic devices in the buildings. A comprehensive and effective energy audit also assesses the building thermally. Heating is a large portion of a building's energy use and must also be considered when performing a technical audit.

2.6.2 Behavioral Energy Audit

The success of an energy audit is dependent on how people interact with the new technology. In schools, human to technology interaction is very frequent. Whether it is a teacher using a projector or the use of lights in a classroom, human to technology interaction is a daily occurrence. Although proposing new light fixtures and installing Energy STAR approved appliances in the school can cut energy costs, it is up to the people to adapt to new routines to conserve energy, making it important to educate teachers and students on how their behaviors impact energy usage.

The purpose of conducting a behavioral assessment is to understand the preconceived notions about energy conservation and to determine how the school uses energy. Do teachers try to use natural light instead of artificial lighting? Do computer labs stay powered overnight? Is the school administration open to the new proposed ideas? How can the school be informed of their energy using habits and how to prevent them? These are all important questions that are addressed by a behavioral energy audit.

2.6.3 Instrumentation

Several auditing tools were available to use through Worcester Polytechnic Institute. From Professor Fred Looft, three main types of instruments were acquired: a thermal-imaging camera (FLIR), two watt meters (one simple and one more complex) and two thermometer USB sticks. These instruments can aid in determining whether a building is both thermally and technically efficient.

To indicate whether buildings are thermally efficient, a thermal imaging camera known as the Forward Looking Infrared camera(FLIR) can be used. The FLIR is a camera that uses infrared radiation rendering to compose an image of heat. The FLIR camera has a resolution of 320 by 240 and has a range of -4°F to 1,202°F (-20°C to 650°C). The FLIR can determine where there are leaks in insulation by comparing differences in surface temperatures. A significant difference in surface temperatures will result in a drastic change of color within the image taken. The purpose of the thermal imaging camera is to be able to inspect the HVAC systems and to find leaks of heat in windows, walls and rooftops.

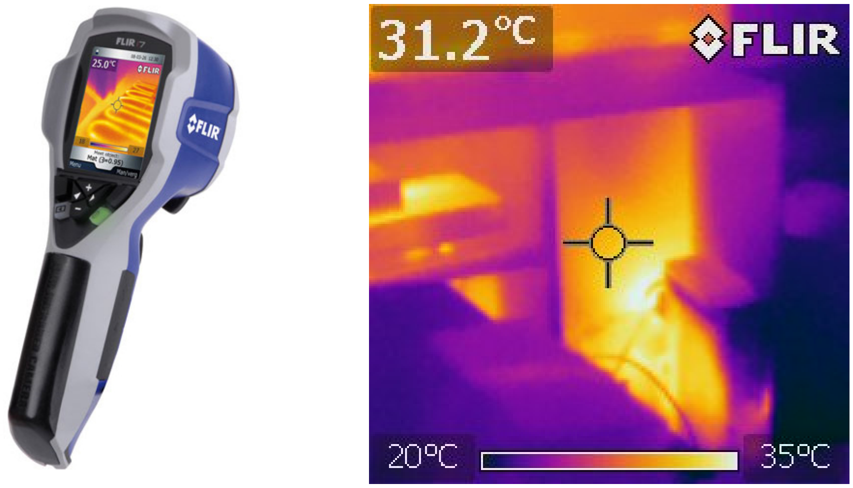

Figure 13: FLIR and Image of Computer under a Desk

The FLIR image in Figure 13 shows a temperature range between 20 Celsius and 35 Celsius (68 Fahrenheit and 95 Fahrenheit respectively) of the surrounding bookshelf and the heat produced by the computer. Another similar tool, shown in Figure 14 is the thermometer USB stick which logs the air temperature in a given space. Since the thermometer USB stick is a small portable instrument**,** it is a useful tool in the sense that it can be stored in HVAC systems without disrupting the system.

Figure 14: Temperature Data Logger

A device that helps measure power usage is the Watt's Up Pro meter, shown in Figure 15 which is an indicator of power use efficiency. The Watt's Up Pro meter is a device that allows the user to measure an electronic voltage, current, power, and energy by being the "middleman" between the appliance and source. This device outputs graphs and spreadsheets of the data collected over a period of time, allowing the user to determine if an appliance is energy efficient.

Figure 15: The Watt's Up Pro Meter

2.6.4 Analytical Resources

Over the years, many companies have developed different types of energy efficient tools and guidelines to analyze the energy management of municipal and residential buildings. Energy STAR, a worldwide known energy efficient company, has developed the Energy STAR Portfolio Manager that is an educational tool that allows the user to track and assess their building's energy and water usage. The portfolio allows the user to input their energy bills, provides an energy outlook, and a statement of energy performance. More specifically it compares buildings and even rooms of similar function to others nationwide. The portfolio also provides guidelines and recommendations for efficient replacements based on the data entered while also checking to see if the buildings are efficient enough to become Energy Star certified and have the potential to received recognition from the Environmental Protection Agency.

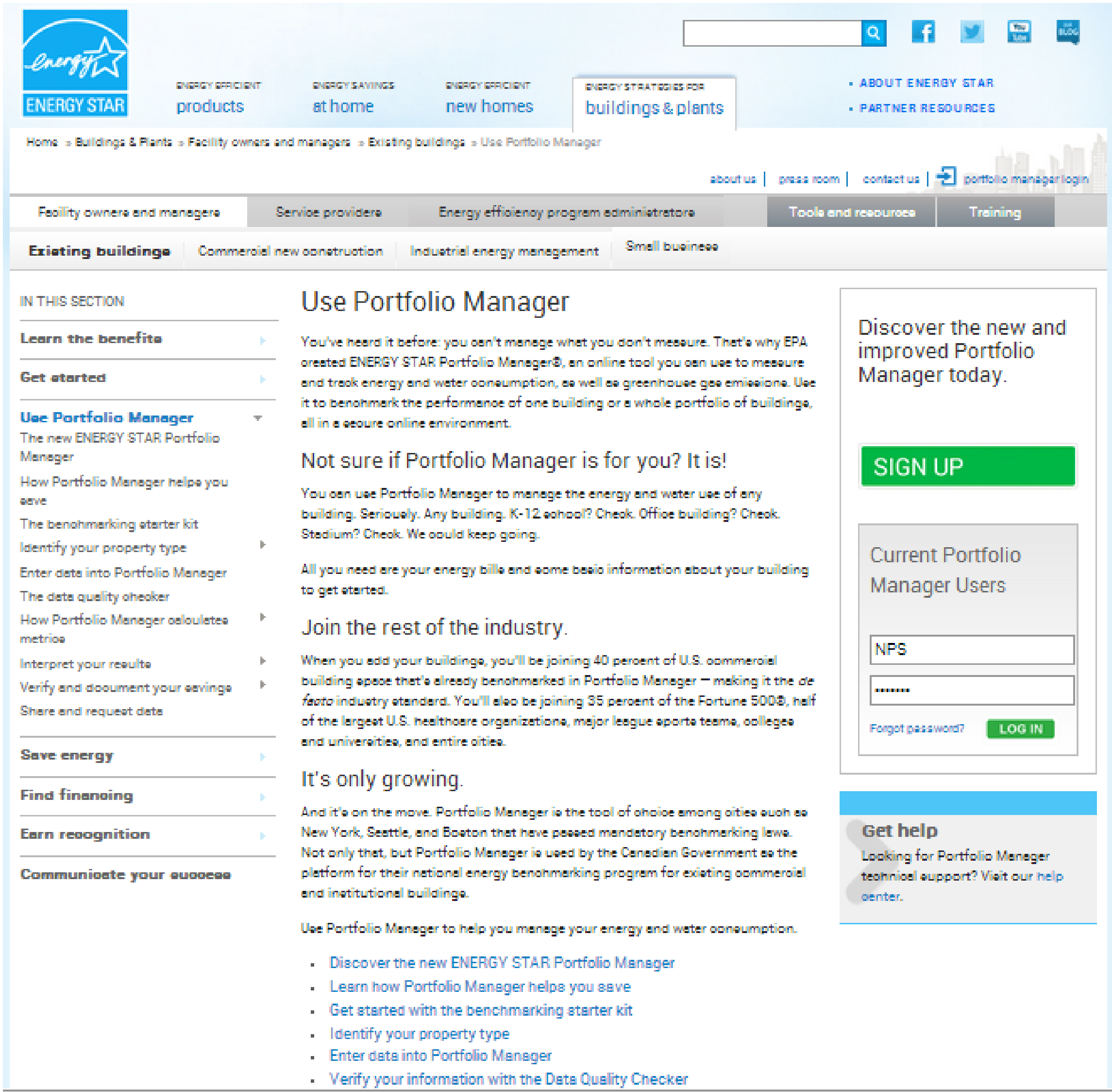

Figure 16: Energy STAR Portfolio Manager (Energy STAR, 2013)

Another tool is the SEE the Light Energy Toolkit which is made specifically for promoting efficiency within the school environment. The on-line toolkit provides schools with benchmarking software, posters, thermometers, and energy audit forms. The benchmarking software allows the user to record and track energy usage within the school buildings. With this information, the toolkit can determine the where energy reductions can be implemented.

Figure 17: SEE the Light Energy Toolkit (SEE the Light, 2013)

2.7 Educational Resources for Energy Conservation

According to ManagEnergy Initiative, it is important to address three missions for education of energy: economy impact, community impact, and energy efficiency benefits (Managenergy, 2006). The following sections describe the importance of each mission.

2.7.1 Economy Impact

The first mission, economic impact, stresses the importance of educating students on rising energy prices and its impact on them. Because public school systems represent a wide range in age amongst their student bodies there are a variety of ages amongst the student body, the resource can be broken down into several focus groups targeting age groups of similar learning ability. Energystar.gov has an existing energy education program integrated for children that covers everything from what energy is, how energy is used, to how people can better conserve energy. Utilizing this education program would be effective for students, grades K-8, because it is an interactive program (Energy STAR, 2013). Because high school students are older and more capable of comprehending environmental impacts, relatable energy facts will be more suitable.

2.7.2 Community Impact

The second mission is educating the community on what they can do. It is important educate people about products that are energy-efficient, as well as educating them on how energy works, how it is used and how much being consumed when using different appliances and electronic devices. Understanding how it works and how much is being consumed will help give a better understanding on how schools can save money and make an impact on society. This all can be done within the relatable energy facts or through the Energy Star Education program explained above, or even through interactive displays such as the showing of differences between LED, incandescent, and fluorescent light bulbs.

2.7.3 Benefits to Energy Efficiency

The third mission is to show the community the outcomes of conserving energy and the impact it has on the schools', or private households' energy bills. The main conflict in the third mission will be retention. To keep the notion of energy conservation relevant and important, the public schools can implement a variety of programs, such as a competition between classrooms to see which classroom is the most energy efficient. Not only does this form excitement for the schools' students, but it also helps further educate them on the principles of energy conservation, a skill they can apply to their own homes. With a growing energy conservative population in Nantucket, the island as a whole will be able to reduce energy consumption if this mission is applied to the Nantucket Public Schools.

2.8 Summary

This section has presented an overview of the necessary background information to understand the premise of project. The section presented an analysis of previously existing research and data that provided historical, technical, sociological, political and economical insight on the project.

3.0 Methodology

The following material presents the goals of our project and the means we have used to achieve them. The specific methods utilized are described in detail.

3.1 Our Mission Statement

The goal of this project was to aid the Nantucket Public Schools in decreasing energy consumption within school buildings. This was accomplished by providing the schools' administration with a detailed assessment of energy consumption patterns in each school building. The analysis consisted of a technical assessment to determine how much energy was being consumed by appliances and electrical devices as well as a behavioral assessment, that identified the practical uses of energy and how energy was being consumed in the school buildings.

Additionally, an educational resource for energy conservation and energy consumption awareness was developed for both the students and faculty of the Nantucket Public Schools in order to reduce energy consumption in the schools as well as in the community of Nantucket. The resource was created using the information gathered from the technical and behavioral assessments and has provided users with information regarding energy, how energy was consumed in Nantucket, how energy was consumed in Nantucket Public Schools, and energy conservation.

3.2 Project Objectives

The objectives of this project were as follows:

- Create an inventory of electrical devices and appliances used in Nantucket Public School buildings
- Determine the total amount of energy consumed by the Nantucket Public School buildings on a monthly and annual basis
- Study energy use by the students and faculty of the Nantucket Public Schools
- Locate areas within the school buildings that can be improved to be more energy efficient.
- Develop educational resources for energy conservation and energy consumption awareness for the students and faculty of Nantucket Public Schools
- Based on the data collected from the Nantucket Public School buildings, develop a detailed report and make recommendations on how the schools can conserve energy and save money

To help visualize and organize the objectives, a flowchart shown in Figure 18 was developed to display the plan and outline for this project. The reduction of energy consumption in Nantucket Public Schools was separated into two different assessments: technical and behavioral.

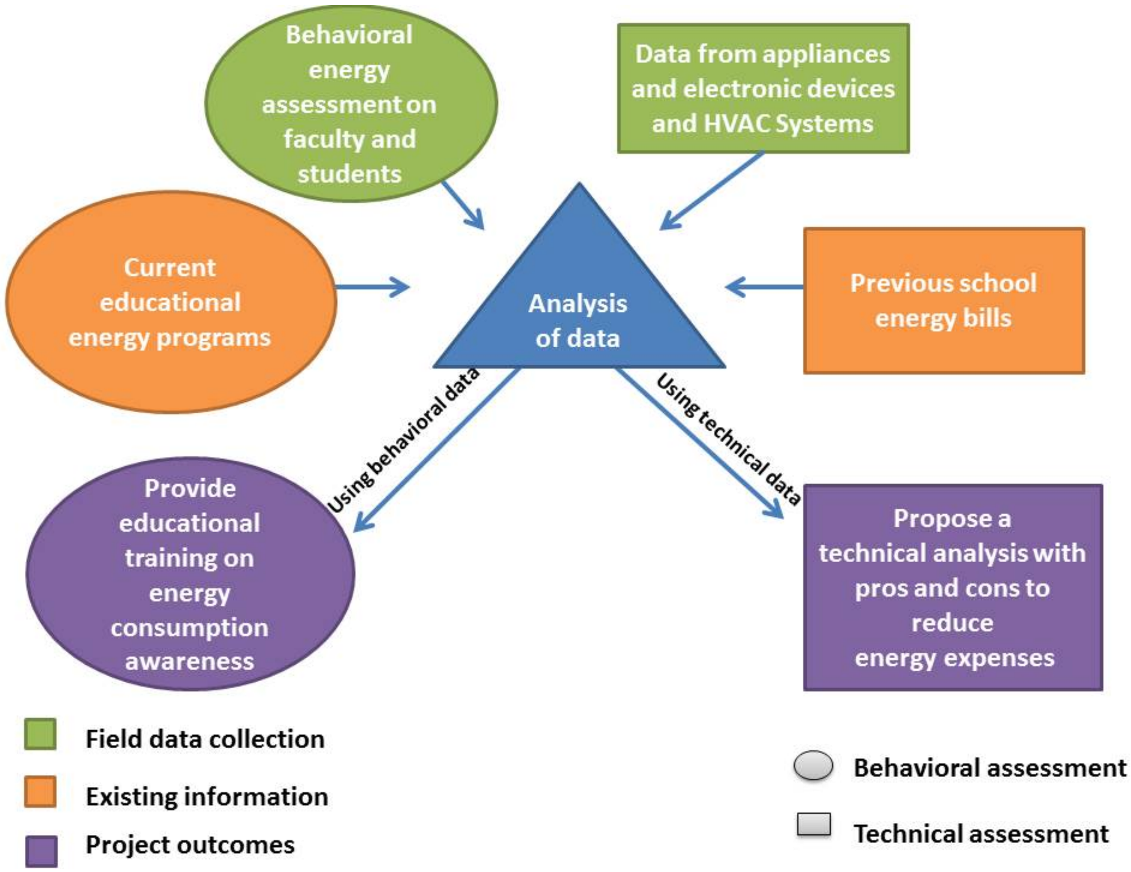

Figure 18: Methodology Flowchart

The first task of the technical assessment was to collect data from appliances and electronic devices used in the schools to accurately measure where energy was being consumed and in what quantities. While this task was being worked on, we also worked on the behavioral assessment task. The first task of the behavioral assessment was to study how students and faculty used energy and the overall behavioral energy consumption by energy users in the schools. This was done by observing behavioral energy use in classrooms and distributing electronic surveys. Surveys were used to help us understand how knowledgeable students and faculty were about energy conservation and how their energy habits affect the total energy consumption in the schools. The information also helped us determine human patterns of electricity usage and how knowledgeable students and faculty were regarding energy conservation. This data gave also provided insight on how willing the school administration, faculty and students were to making changes in their day-to-day routines to conserve energy.

Once the preliminary tasks of both the behavioral and technical assessment were complete, a technical and behavioral analysis was performed. The technical analysis was based on a systematic analysis of the data using a cost benefit analysis approach to determine the highest energy efficient solutions for managing the schools' appliances and electronic devices. The behavioral analysis consisted of using the survey, interview, and observational data collected to develop an educational energy resource. A timeline summarizing the tasks we performed to complete this project can be seen in Table 2.

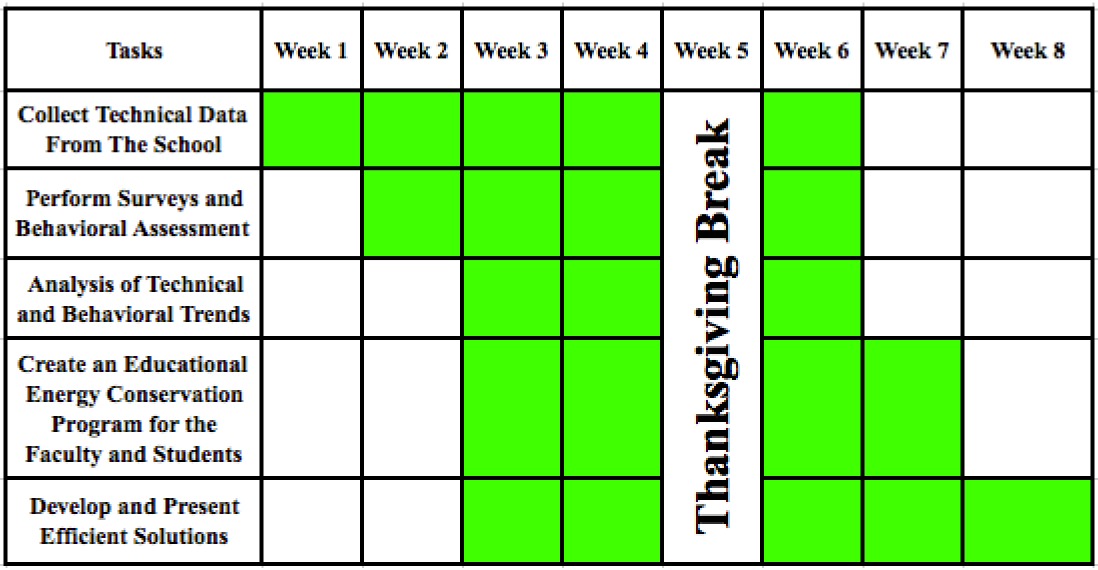

Table 2: Project Timeline

3.3 Measuring Energy Use in Nantucket Public Schools

In order to reduce the total energy use in Nantucket Public Schools, it was important to know where energy was being consumed in the schools. We obtained this total by analyzing the schools heating and electric bills and collecting data from many different areas of the schools: classrooms, teacher's lounges, gymnasiums, cafeterias, libraries and hallways. A map and plan were made to route and conduct our audit both effectively and efficiently. To facilitate collecting this information, a general checklist was created. The checklist was used to inventory appliances and electronic devices throughout the rooms. Examples of appliances and devices inventoried are mini fridges, computers, and microwaves.

3.3.1 Analysis of Previous Energy Bills

Obtaining previous energy bills from Nantucket Public Schools provided us insight on the energy consumption and the breakdown of the energy budget within the schools. The data from the bills provided us with consumption patterns on a monthly and annual basis. The bills also indicated the magnitude of savings that can be made from conserving energy and reducing energy consumption. A complete distribution of Nantucket Public School's total energy costs by utility can be found in Appendix E.

3.3.2 Analysis of Electricity Usage

Since appliances/electrical devices come in various models and brands, random devices were selected to represent the common appliance/ electrical device for our study. Energy usage of an electrical device or appliance was determined through different meter settings provided by a non-logging kilowatt meter which allowed us to view the voltage, watts and current levels being drawn by the device. For further analysis of larger energy consuming devices or appliances, the Watt's Up Pro meter, shown previously in Figure 15, was used to record energy usage over a 24 hour time period. This data helped determine the amount of energy used by the electrical devices or appliances that were plugged into the meter at a specific location. In aggregate and after extrapolation, the meter provided readings of the total energy consumed by the device, or appliance being tested and also provided the period of time the appliance or device was used during the day. The energy use from the appliance or device was then compared to energy efficient models to determine which appliance or device was more energy efficient. Based on these results, recommendations were developed and provided to Nantucket Public Schools' administration.

3.3.3 Analysis of HVAC Systems

Heating and cooling systems make up a significant portion of Nantucket Public Schools energy bill. Both the Nantucket Elementary School building and the building containing Cyrus Pierce Middle School and Nantucket High School are heated by hot water HVAC systems. These systems are dependent on oil and water. Nantucket Public Schools also pays for gas to heat the Nantucket High School pool. Oil, water, and gas account for 58% of the Nantucket Public Schools' annual utilities cost (See Appendix E).

Because oil and gas are primarily used to heat and cool the school, we took steps to assess the Nantucket Public Schools' current Heating Ventilation And Cooling (HVAC) systems and it's efficiency. Within different areas in the schools, the USB temperature loggers were placed to record air temperature. The air temperature data was compared to the controlled thermostat for each building to determine if the system was working properly and if the room was properly insulated.

A tool used to check for thermal energy leaks was our FLIR camera. The pictures taken from the FLIR helped locate areas where there were leaks in insulation and identify where heat was escaping from the buildings. The FLIR was primarily used to assess the insulation of windows, doors and walls. When leaks were identified, the Infrared Thermometer was used to give exact temperature readings of different surfaces. These tools were used to determine the efficiency of the current HVAC systems in the schools.

3.4 Profile Energy Use by Students and Faculty

Human behavior can negatively impact the amount of energy being used. Examples include electronic devices such as projectors that are left on or plugged in, classrooms that do not utilize natural lighting and instead keep lights on during the day, and hallway lights left on during non-school hours. Understanding human behavior associated with energy use in the schools has helped determine where energy was being used inefficiently which provided data for a more accurate proposal on how to reduce energy consumption.

3.4.1 Surveys

To obtain information about how knowledgeable the faculty is and how they felt about energy consumption and conservation, we chose to use the methods of surveys and classroom observations. We created two different surveys for the Nantucket Public Schools' staff. The first survey was designed to gauge existing knowledge and opinions of the faculty regarding energy, energy consumption, and energy conservation. The second survey was designed to identify the behavioral uses of electricity in the schools and assess the control and efficiency of the HVAC systems. These surveys consisted of two types of questions: open and closed. Open questions are categorized as questions with no definite answers. These questions were designed to gauge the opinion of the survey subjects and allow them to answer freely without being constrained to specific answer choices. The closed questions offered a finite number of choices and were intended to provide us with statistical data to better understand energy use in the schools. These surveys were distributed electronically via email to the entire staff of Nantucket Public Schools. To increase the sample size of our second survey, we sent multiple email reminders including a link to the survey for easy accessibility to the survey. The complete first and second surveys can be found in Appendices G and H respectively.

3.4.2 Classroom Observations

We performed classroom observations by sitting in on classes during school hours to study human routines and behaviors in regards to energy consumption. Classrooms were randomly selected in Nantucket High School and by the recommendation of the school principals for Nantucket Elementary School and Cyrus Pierce Middle School. This provided us with a first-hand perspective on the typical use of energy in the classroom setting.

3.5 Development of Technical and Behavioral Solutions for Energy Conservation

After collecting data on the amount of energy used and behavioral trends, energy conservations strategies and suggestions were developed. The technical data collected was used to create a proposal of the advantages and disadvantages of energy efficient solutions as well as a cost benefit analysis. The data was then used to create a profile of Nantucket Public Schools. The profile will help track specific energy use within the school buildings and compare them to national standards of green buildings. An educational program has also been designed to help students and faculty within the Nantucket Public School system reduce energy consumption and educate them on the positive outcomes of energy conservation.

3.5.1 Technical Solutions: Developing Energy Reports

To provide solutions for our technical assessment of the Nantucket Public Schools, we used many different techniques to organize our data and present our analysis. We created an Energy STAR Portfolio manager for the Nantucket Public Schools. To update this portfolio, we entered information about the school buildings and property as well as past monthly energy bills. We then used the information gathered from our field data collection and past energy bills to create a cost benefit analysis for the Nantucket Public Schools.

3.5.2 Behavioral Solution: Develop an Educational Resource in Energy Conservation

To help the Nantucket Public Schools reduce the amount of electricity they consume, it was important to educate students and faculty on how electricity is transferred to Nantucket and how it is consumed. The more aware students and faculty are of how electricity works and how it appears on an electricity bill, the more energy conservative people will behave. From the behavioral data obtained through surveys and classroom observations, a website was developed to teach students and faculty how to conserve energy.

As an educational resource for the Nantucket Public Schools, we created an energy conservation website. The website was designed to integrate all three educational ManagEnergy missions (referenced in section 2.7), providing relatable energy facts, videos, interactive games, and up to date polls of potential energy competitions. We also integrated QR codes to our website where different energy topics are represented by different QR codes. The QR codes were then placed on SEE the Light energy conservation tip posters. We then hung up the posters on several bulletin boards throughout the school so they are accessible to the students and faculty. An example of one of the posters is shown in Figure 19.

Figure 19: Educational Energy Poster with QR Code

4.0 Results and Findings

After applying our methods to the Nantucket Public Schools, we obtained results that have helped us determine ways for Nantucket Public Schools to reduce energy consumption. Additionally, we have created educational resources regarding energy awareness and conservation for the students and staff of the Nantucket Public Schools as well as the general public.

4.1 Survey Data

To help us gain a better understanding of energy use in Nantucket Public Schools we administered two different surveys to the staff of all four schools. A Worcester Polytechnic Institute survey building software called Qualtratics was used to develop and analysis both surveys. The identity of the respondents remained anonymous; however, the first survey asked a series of demographic questions the survey sample size for each school of each school. The following sections discuss the results of our surveys.

4.1.1 Survey 1 Results

The first of the two surveys was designed to evaluate the staff's knowledge of energy consumption, energy conservation and general attitude towards energy. The full survey can be found in Appendix I. We received 69 total survey responses from the first survey. The results to the questions along with a brief analysis of each are listed below. We have omitted the results to question 2 which asks the respondent to share their current job position.

Question 1: What grade(s) do you teach? If you are not a teacher, select "other". If you do not wish to answer this question please select "Do not wish to specify". (You may choose more than one answer).

#	Answer	Bar	Response	%
1	Pre-K		1	1.56%
2	Kindergarten		5	7.81%
3	1st grade		5	7.81%
4	2nd Grade		6	9.38%
5	3rd Grade		6	9.38%
6	4th Grade		6	9.38%
7	5th Grade		4	6.25%
8	6th Grade		8	12.50%
9	7th Grade		6	9.38%
10	8th Grade		6	9.38%
11	9th Grade		18	28.13%
12	10th Grade		18	28.13%
13	11th Grade		18	28.13%
14	12th Grade		15	23.44%
15	Other		23	35.94%
16	Do not wish to specify		1	1.56%
	Total		146	100.00%

Table 3: Survey 1, Question 1 Results

From the results of our first question we can conclude that the majority of our respondents were teachers of Nantucket High School. These results are what we expected, as the Nantucket High School has the largest number of employees of the four public schools. Another observation we made from these results is that 36% of the responders answered “Other”, signifying that many other departments other than teachers such as the administration, guidance and custodial staffs completed the survey.

Question 3: Which building do you spend most of your time working in?

#	Answer	Bar	Response
1	Nantucket Elementary School		23
2	Cyprus Middle School		9
3	Nantucket High School		29
4	Community School		3
	Total		64

Table 4: Survey 1, Question 3 Results

Question 3's results confirmed the assumption we made after reading the results to question 1. The most common result was Nantucket High School making up for 45% of the answers. It is however closely followed by Nantucket Elementary School, which accounted for 36% of the answers.

Question 4: For each of the following statements, please select the answer that best describes your personal energy use in school buildings.

#	Question	Never	Rarely	Sometimes	Often	Always	Response	Average Value
1	I turn off the lights when I leave a room.	1	3	18	19	23	64	3.94
2	I use natural light in the classroom or office in place of artificial lighting.	19	10	16	15	4	64	2.61
3	I turn off computers when not in use.	16	15	13	10	10	64	2.73
4	I turn off computer monitors when not in use.	15	15	8	9	17	64	2.97
5	I turn off projectors when not in use.	4	1	4	4	51	64	4.52
6	I unplug chargers and other small electronic devices when not in use.	12	12	12	8	20	64	3.19

Table 5: Survey 1, Question 4 Results

Question 4 provided insight to the existing habits that the Nantucket Public Schools' staff has regarding energy use. Five of the six opinion statements given in question 4 resulted in the majority of answers being "Sometimes". There were two statements however which resulted in strongly opinionated results. The two most common results to the first statement, "I turn off the lights when I leave a room," were "Always" and "Often", making up for 66% of the answers. The survey results also indicate that nearly 80% of teachers report that they *always* turn off their projector when not in use. We can conclude that at least in these areas, teachers practice energy conservation.

Questions 5: For each of the following questions, please make a selection within the range that best represents your opinion.

#	Question	Never	Rarely	Sometimes	Often	Always	Response	Average Value
1	Conserving energy in Nantucket Public Schools is not very important to me; I don't pay the bills so why should I care?	44	10	4	5	1	64	1.58
2	I have little control over the amount of energy used in this facility, so even if I tried to conserve energy it wouldn't make a difference.	30	15	13	5	1	64	1.94
3	Energy Conservation is an important issue these days so people should try to do everything they can at home and in the schools to save energy.	1	1	4	17	41	64	4.50
4	If I tried to conserve energy I'd have to give up certain comforts and conveniences and I don't want to do that.	26	23	12	2	1	64	1.89

Table 6: Survey 1, Question 5 Results

After distributing the survey, we determined that the answer range for this question is inappropriate for the questions. We did not use the data collected from question 5 at any point during our analysis of data, and instead, rewrote and asked the question with a more appropriate range of answer options in our second survey to the staff.

Question 6: In what ways do you believe you contribute to energy conservation in Nantucket Public School buildings?

other than turning off lights I am not sure if I do help conserve energy
I always unplug my cell phone charger when not in use, keep the light off in my bathroom (attached to my office) do not have a coffee maker, fridge etc in my office. I use lamps with energy efficient bulbs to light my office rather than the overhead lights. Unfortunately I have no natural light in my office so that is not an option for me.
I have complained in the past of water continuously running in the pool showers (finally fixed it after several years!). Also, asked about rooms that were so overheated in winter that teachers were opening windows though it was freezing outside. This is still a problem, but hopefully won't be the case when it gets cold this winter.
Besides turning of lights (including in the bathroom), i also try very hard to be as "green" as possible when dealing with paper. I have the students working on line and passing in assignments by sharing them with me in google docs or by emailing me. This way, I do not use the photocopy machine as much as other teachers. Also, by using technology we do a lot of group discussions, so most of the time, I am the only one with an electronic device going.
turnings off lights, recycling
Putting everything in my classroom to sleep every day. Turning off lights when possible.
Turn off lights when not in room. Shut down computers at end of work day. Unplug pencil sharpeners and CD/tape players when not in use.
I always shut down my computer at the end of every day
Well, I don't use extra gadgets.
Turn lights off when I leave my office

Table 7: Survey 1, Question 6 Results

Question 7, is an open survey question that resulted in a wide variety of answers, indicating that the majority of the staff has limited knowledge on how to conserve energy.

Question 7: What conscious efforts do you make daily to conserve energy?

turn off lights unplug devices keep heat at a lower setting wear extra layers
I use energy efficient bulbs in my home, am mindful of heating and cooling and do so only as necessary, I unplug appliances and cell phone chargers and I turn off lights when not in use.
I shut lights off in my house when they're not being used. We heat our house with wood, and recently bought a much more energy efficient one in hopes of burning less fire wood. I limit extra trips in my car to save on gas, since I live six miles away from town.
see above questions and responses
turning off lights
Lots of stuff at home, lowering heat, turning off all lights etc for day, lowering heat every night for overrnight.
See above.
being mindful of shutting off lights, closing doors, turning equipment off
I have very little control here, but do prefer natural lighting. We were told at one time that the bulbs are energy efficient and that it was actually better to not always be turning them on and off.
Turn off lights, monitor, use natural light when possible

Table 8: Survey 1, Question 7 Results

Table 8 displays a sample of the answers we received from question 7, one of our open survey questions. Many of the survey responders answered that they try to turn lights off when they are not necessary. One answer we noted was "I have very little control here, but I do prefer natural lighting. We were told at one time that the bulbs are energy efficient and that it was actually better to not always be turning them on and off". Although there is no validity to this statement is does offer perspective to the attitude of some of the staff. The individual, them self, is indicating that he/she is energy conscious and tries to minimize the electricity consumed by artificial lighting. What is concerning is that s/he states that they have been given false information. Although the current bulbs used in the Nantucket Public Schools were recently installed during the Northern Energy Systems' comprehensive lighting audit they are 25 Watt bulbs. They require little to no electricity to power on and off, so turning one light off for one hour would save 25 Watt-hours of electricity.

Question 8: What do you believe consumes the most amount of energy during your daily school routine?

Copy machine, in class room fans. The copy machine constantly jams and as a result jobs need to be done over and over I consider this a waste of energy and time.
My computer and lights.
As a TA in many classrooms, I don't have much control of energy use. However, I do turn off lights whenever I'm the last one leaving a room (including faculty bathrooms). I will often turn off smart board projectors I see left on too. I think heating the building in winter is probably greatest use of energy. Some teachers have fridges and microwaves in their room. I occasionally use the ones in the faculty lounge.
lights - but in the winter, perhaps the boiler system
lights, computers
My room has a smartboard w/ projector, two teacher computers and 30 laptop pc's. so there's that. Plus we have no windows so I run a fan or two pretty much all the time.
Overhead lighting in classrooms and common areas; heating/ventilation blowers.
inefficient air/heat
Heat. Turn it down, I have a sweater. But the computers must use a lot of energy, plus they seem to require air conditioning.
Computer

Table 9: Survey 1, Question 8 Results

Question 8, another open survey question, resulted in a wide variety of answers, indicating that the staff has any different perspectives on what they believe consumes the most energy in the schools. This large spread of answers also implies that there is much room for improvement regarding the faculty's overall knowledge on energy consumption. Some of the more common responses to this question included the HVAC systems, the lights, SMART Boards, and computers.

4.1.2 Survey 2 Results

The second of the two surveys was intended to provide us with more statistical data regarding energy use in the schools. It asked questions about personal appliances and electronic devices, energy educational resources, and the efficiency of the schools' HVAC systems. We initially received only 58 results. To improve this sample size we sent out email reminders to the staff and set a deadline for surveys to be taken. This increased our sample size to a total of 108 responses. The results to the questions are listed below.

Question 1: For each of the following statement, please make a selection within the range that best represents your opinion.

#	Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Response	Average Value
1	Conserving energy in Nantucket Public Schools is not very important to me; I don't pay the bills so why should I care?	75	26	4	-	2	107	1.39
2	I have little control over the amount of energy used in this facility, so even if I tried to conserve energy it wouldn't make a difference.	35	47	8	15	2	107	2.08
3	Energy Conservation is an important issue these days so people should try to do everything they can at home and in the schools to save energy.	11	1	2	27	66	107	4.27
4	If I tried to conserve energy I'd have to give up certain comforts and conveniences and I don't want to do that.	31	48	18	10	-	107	2.07

Table 10: Survey 2, Question 1 Results

Question 1 of the second survey was the same as question 5 of the first survey. We had determined that the answer selection scale ranging from "Never" to "Always" was inappropriate for the question. We duplicated the opinion statements from question 5, but changed the answer choices to range from "Strongly Disagree" to "Strongly Agree". Each of the four opinion statements resulted in responses heavily favoring one side of the opinion range. Responders tended to either "Strongly Disagree" or "Disagree" with statements 1, 2, and 4 and either "Strongly Agree" or "Agree" with statement 3. All of these results indicate that the Nantucket Public Schools staff have a strong opinion about energy conservation and believe that it is a very important issue.

Question 2: Please check all the following appliances that are in your office, classroom or workplace. If there are any others not listed below that you can think of, please select other and write in your answer.

#	Answer	Bar	Response	%
1	Keurig		13	13.98%
2	Coffee maker		5	5.38%
3	Mini Fridge		55	59.14%
4	Microwave		34	36.56%
5	Hot Water maker		7	7.53%
6	Toaster		7	7.53%
7	Smartboard		43	46.24%
8	Other		27	29.03%
	Total		191	100.00%

Table 11: Survey 2, Question 2 Results

Question 2 yielded results that were later confirmed by our inventory collection. We asked teachers to check all answers applicable to their workspace. An observation we made is that 55 responders stated that they have a mini refrigerator in their classroom or office. This was the highest response of the appliances followed closely by the SMART Board. The difference to note between the devices is that the SMART Board is entirely used for educational value whereas a mini refrigerator is for personal use. The mini fridge also has one of the highest rates of electricity consumption of all of the answer options.

Question 3: Please use the sliding scale to indicate how you feel about removing personal appliances from classrooms and replacing them with common appliances in common areas and teachers' lounges (The left most face being extremely discontent, the middle face being indifferent, and the right most face being extremely content).

#	Answer	Bar	Response	%
1			26	31.71%
2			15	18.29%
3			7	8.54%
4			15	18.29%
5			19	23.17%
	Total		82	100.00%

Table 12: Survey 2, Question 3 Results

Question 3 offered five images of faces with different levels of emotion to choose from to represent the responder's opinion on the statement. Although we thought this would be an amusing and simple way to collect data for the question, we found that only 76% of survey takers completed this question. The question resulted in a fairly even spread of answers. Although 32% answered "Extremely Discontent", 50% of responders stated that they felt "Indifferent" to "Extremely Content" about having personal appliances removed from their classrooms.

Question 4: Please select the answer for each of the following statements that best represents your personal opinion. (Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree)

#	Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Response	Average Value
1	Current energy initiatives are visible and recognizable	15	29	28	27	5	104	2.79
2	I feel I have been adequately educated on how to effectively conserve energy.	7	24	24	38	10	103	3.19
3	I am interested in participating in energy conservation projects for Nantucket Public Schools and for the community of Nantucket.	5	4	28	43	24	104	3.74
4	I would like to see more visible reminders about energy consumption and energy conservation tips.	3	2	16	54	28	103	3.99

Table 13: Survey 2, Question 4 Results

Question 4 was designed to collect additional data about the attitude of the Nantucket Public Schools regarding energy conservation and energy knowledge. Responses for questions 1 and 2 reflected mostly moderate opinions. The staff slightly disagreed with the first statement and very slightly agreed with the second statement, which tells us that energy initiatives are not very visible and recognizable and that the staff as a whole is not confident in their energy conservation knowledge. We did see positive results from questions 3 and 4 indicating that the staff is interested in participating in energy projects and would like to see more visible reminders about energy conservation.

Question 5: Do you use surge protectors to power multiple electronic devices?

#	Answer	Bar	Response	%
1	Yes		83	82.18%
2	No		18	17.82%
	Total		101	100.00%

Table 14: Survey 2, Question 5 Results

We asked question 5 because there are many energy conservation techniques that can be practiced using surge protectors. For example, there are newer models of surge protectors which have automatic shut-off features. These surge protectors completely power down devices after they have been in "standby", or "sleep" mode, eliminating phantom loads of electricity. Surge protectors can also be used to manually power down several electronics with one master switch. The overwhelming response that staff members do use surge protectors implies that there are possibilities to reduce energy consumption.

Question 6: How often do you use your smart board? If you do not have a smart board in your classroom or office space, please select N/A.

#	Answer	Bar	Response	%
1	Everyday		33	62.26%
2	2-4 times per week		13	24.53%
3	Once per week		0	0.00%
4	2-3 times per month		1	1.89%
5	Once per month		0	0.00%
6	Never		6	11.32%
	Total		53	100.00%

Table 15: Survey 2, Question 6 Results

When conducting our inventory of appliances and electronic devices in the Nantucket Public Schools, we noted that nearly all classrooms were equipped with a SMART Board. We also observed that they were all plugged in to an electrical outlet. We asked question 6 to find out if the boards were a frequently used devices, or if they were rarely used and drawing phantom loads of electricity. The survey responses indicated that they are used very frequently, with the exception of a small percentage of teachers, who do not use them at all.

Question 7: If you have a SMART Board in your classroom, describe how you use the applications in your teaching. If you do not have a SMART Board, please type the response "N/A" (i.e. I write on the smart board to show students how to solve a math problem. I use the smart board create notes that I can hand out to students).

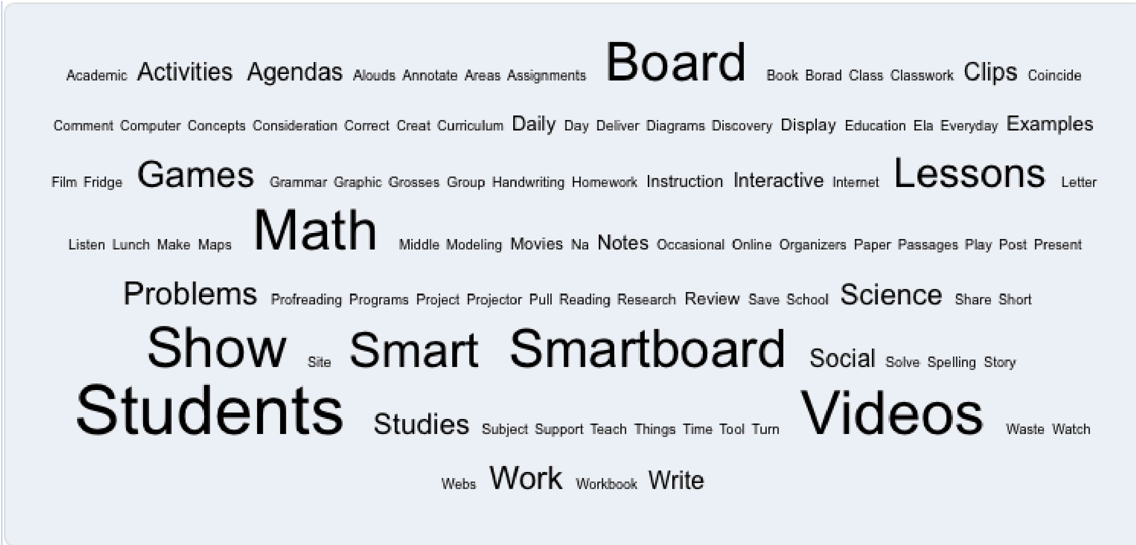

Table 16: Survey 2, Question 7 Results

Question 7 was asked as a follow up to question 6. The Qualtratic software developed the word cloud[2] above by emphasizing more frequent responses in a larger font size. Although we concluded that SMART Boards are used very frequently, we asked survey subjects to describe how they use the SMART Board to reinforce that it is used for its applications and electronic uses, rather than just as a common white board. We did find that survey responders answered that they were used for their distinguishing features and not being used as an energy consuming, common white board.

[2] an example of free word cloud generators is here: http://www.edudemic.com/9-word-cloud-generators-that-arent-wordle/

Question 8: Does your classroom or office experience any kind of outside disturbance from the wind turbine, such as light flickering or noise? If you select "Yes", please elaborate.

#	Answer	Bar	Response	%
1	No		88	83.81%
2	Yes		17	16.19%
	Total		105	100.00%

Table 17: Survey 2, Question 8 Results

Question 8 asked the staff if they experienced any negative impacts from the wind turbine. We asked this because we had researched wind energy projects on Nantucket and found that in the past there have been unsuccessful projects causing them to be a controversial topic amongst islanders. 84% of responders said that they did not experience any effect from the turbine. Of the 17 who answered "Yes" to the question, 12 provided us with their personal experiences. Of the 12, only one indicated any sort of frustration or ill-feelings toward the subject matter. Several responders did tell us that it was a minor inconvenience and did not at all trouble them.

Question 9: During this time of the year, I find my classroom/office's temperature to be __________.

#	Answer	Bar	Response	%
1	Cold		12	11.76%
2	Cool		24	23.53%
3	Comfortable		35	34.31%
4	Warm		16	15.69%
5	Hot		15	14.71%
	Total		102	100.00%

Table 18: Survey 2, Question 9 Results

Question 9 was designed to assess the heat control within the buildings. We received a relatively even spread of results, the most common result describing the temperature being "comfortable". The second highest result was "cool". This result was expected as it is asked specifically during the fall/winter season transition. The even distribution of answers to this question indicates that heating control at this time of the year is not an issue.

Question 10: Which of the following best describes an action you normally take when you find your classroom/office to be too warm?

#	Answer	Bar	Response	%
1	Open a window		27	25.00%
2	Remove a layer of clothing		41	37.96%
3	Contact the facilities department		20	18.52%
4	Nothing		6	5.56%
5	Other		14	12.96%
	Total		108	100.00%

Table 19: Survey 2, Question 10 Results

Question 10 was asked to determine how staff handled the issue under circumstances when heat was poorly controlled. The standard protocol the school has in place is to contact the facilities department who can control the buildings' heat and make adjustments when temperatures are not comfortable. Only 19% of staff members reported that they followed this protocol. What is more concerning is that 25% of the staff reported that they open a window to deal with a warm room. This solution may alleviate the warm temperature, but does not stop the radiator from producing warm air. This results in wasted heating, costing the schools money.

Question 11: Which of the following best describes an action you normally take when you find your classroom/office to be too cold?

#	Answer	Bar	Response	%
1	Add a layer of clothing		76	70.37%
2	Contact the facilities department		16	14.81%
3	Nothing		7	6.48%
4	Other		9	8.33%
	Total		108	100.00%

Table 20: Survey 2, Question 11 Results

Question 11 was designed similarly to question 10, but for a different situation, when the room is too cold. Only 15% of survey responders answered that they contact the facilities department. The small percentage that answered this for both heat control questions suggests that the majority of Nantucket Public Schools' staff is either unaware of the protocol for heat control, or is not motivated to follow the policy.

Question 12: At what temperature is your thermostat at home typically set to? (°F)

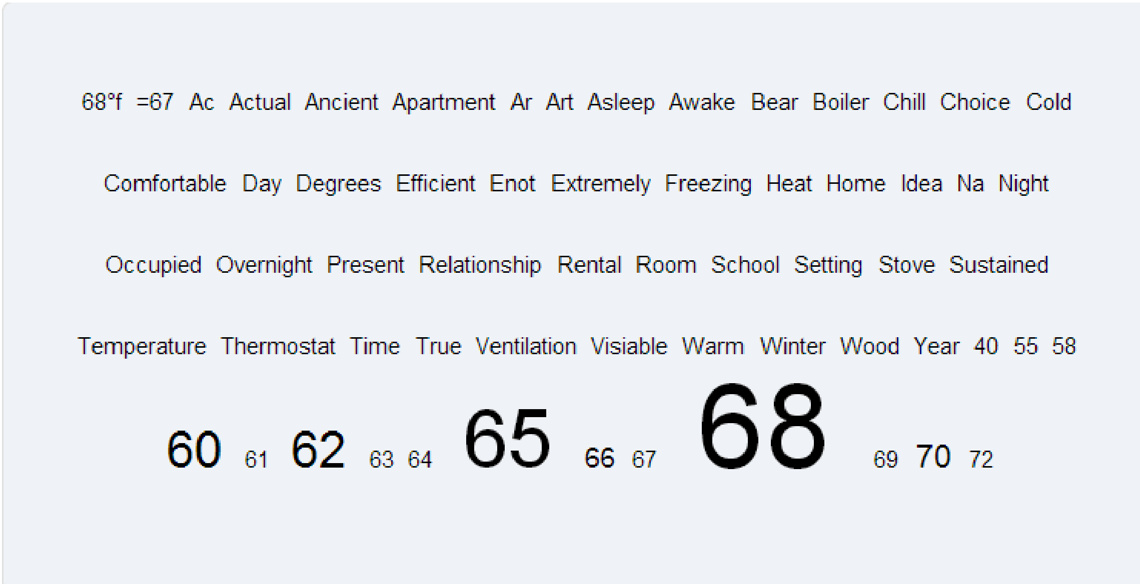

Table 21: Survey 2, Question 12 Results

As noted before, the Qualtratic software developed the image above by emphasizing more frequent responses in a larger font size. The average temperature from the responses from question 12 was 65.4 *°F*. The mode of the responses was 68 *°F*.

Question 13: How likely are you to integrate energy consumption awareness and energy conservation topics into your curriculum if given the materials and resources? If you do not teach please select N/A.

#	Answer	Bar	Response	%
1	Very Unlikely		4	5.56%
2	Unlikely		7	9.72%
3	Somewhat Unlikely		7	9.72%
4	Unsure		11	15.28%
5	Somewhat Likely		14	19.44%
6	Likely		13	18.06%
7	Very Likely		16	22.22%
	Total		72	100.00%

Table 22: Survey 2, Question 13 Results

Question 13 was designed to determine the willingness of teachers to provide energy education. Our results show positive responses indicating that staff is open to the idea of integrating energy education to their curriculum.

4.2 Room Inventory

From our inventory we discovered several personal appliances such as miniature refrigerators, microwaves, lamps and printers. We totaled all of the devices found in the four public schools and created a comprehensive inventory of each school. The inventory of the four schools can be seen in Appendices A-D. A Microsoft Excel sheet which also includes the energy use from our data collections as well as typical hours the device is used per week and approximate energy consumption of each device per week was also created. Table 23 is an inventory of appliances and electrical devices in the Nantucket Public School buildings.

Total Inventory in NPS	
Appliance/Device	Quantity
Tube Lights	5,712
Desktop Computers	591
Mini Fridge	61
Microwave	34
Faucets	288
Projector	66
Smart Board	76
Fan	79
Laptops	148
Lamp	67
Keurig	17
Printer	55
Coffee Maker	8

Table 23: Inventory of Appliances and Electronic Devices in Nantucket Public Schools

4.3 Classroom Observations

Over the course of three weeks, our team observed 13 classes at Nantucket Public Schools. Each class observation typically lasted 2 hours and had 1-3 team members observing. Throughout the duration of class time, each observer would complete an observation sheet, which asked the observer to elaborate on different aspects of energy use in the classroom, such as heating, lighting and electricity use. The template used to complete these observations can be seen in Appendix N. A map of each school with observed classrooms labeled can be found in Appendices K, L and M.

During these observations we noticed that classrooms ranged from being noticeably cold to uncomfortably warm (likely not "hot") depending on where the room was located within the school. Many teachers commented that their room experienced heating inconsistencies and were often uncomfortably warm. Another observation was that some teachers used artificial light on sunny days, leaving the blinds drawn. Other key observations were that there were often electronic devices turned on, or plugged in when not in use. We found that most unused computers were turned and had monitors in standby mode. SMART Boards were very often used during class time. Although some teachers would turn off the board when not in use, we often found that teachers would leave the board running after its use.

At the end of each class observation, we conducted a brief interview with the teacher. The interviews generally followed the same five question format listed below. The interview template we used to conduct these interviews can be found in Appendix O.

1. What specific ways do you use energy during class time? What personal efforts do you make to conserve energy in the schools?
2. Can you briefly describe energy use in Nantucket Public Schools? How do you feel about how Nantucket Public Schools uses energy?
3. Based on your answer to the previous question, what is one thing you would change about energy use in Nantucket Public Schools in order to conserve energy.
4. How would you describe the heating in this classroom? Do you notice it being too warm, too cold or comfortable?
5. Do we have your consent to use the information we have gathered through observations and your answer to these interview questions in our final report.

After completing these interviews with teachers, we found many recurring responses. When we asked what specific ways teachers used energy during class time, the most common responses were the use of the SMART Board, computers, and lights. Many teachers also voiced concerns regarding the control of the heating system noting that their rooms often experience extreme temperatures. In general, teachers tried to conserve energy in their classroom, they were unsure of the impact their personal efforts could have on the Nantucket Public Schools. Several teachers mentioned that accessible information about energy conservation techniques and the impacts they have would be motivating and helpful to them.

4.4 Electrical Devices and Appliances Data

To better understand how electricity is being consumed we took several energy readings using the Watt's Up Pro meter, which indicated the amount of electricity a particular device used over a period of time. The recorded energy consumption was then used to approximate the total cost to operate each device.

4.4.1 Refrigerator

We tested the energy consumption of three different types of refrigerators, the Summit mini refrigerator, the Woods standard sized refrigerator, and the General Electric mini refrigerator. Figure 20 is an image showing the three brands of refrigerators tested. We first tested the Summit brand mini refrigerator located in the teachers' lounge of the Nantucket Elementary School. We chose to test this particular refrigerator because it was a very common brand found within the school and the one we tested was located in an area in which we predicted would experience a lot of usage. The second refrigerator we tested was the Woods standard size refrigerator located in the teachers' lounge of Nantucket High School. We chose this model because it would also be used throughout the day and would provide data for a larger sized refrigerator. Because there were several models of mini refrigerators, we then tested a second common model, General Electric, in order to compare which brand was more energy efficient. All of the energy readings were taken over a 24 hour period of time. The results from these readings are graphed in

Figure 21.

Figure 20: The Refrigerators: General Electric, Summit and Woods

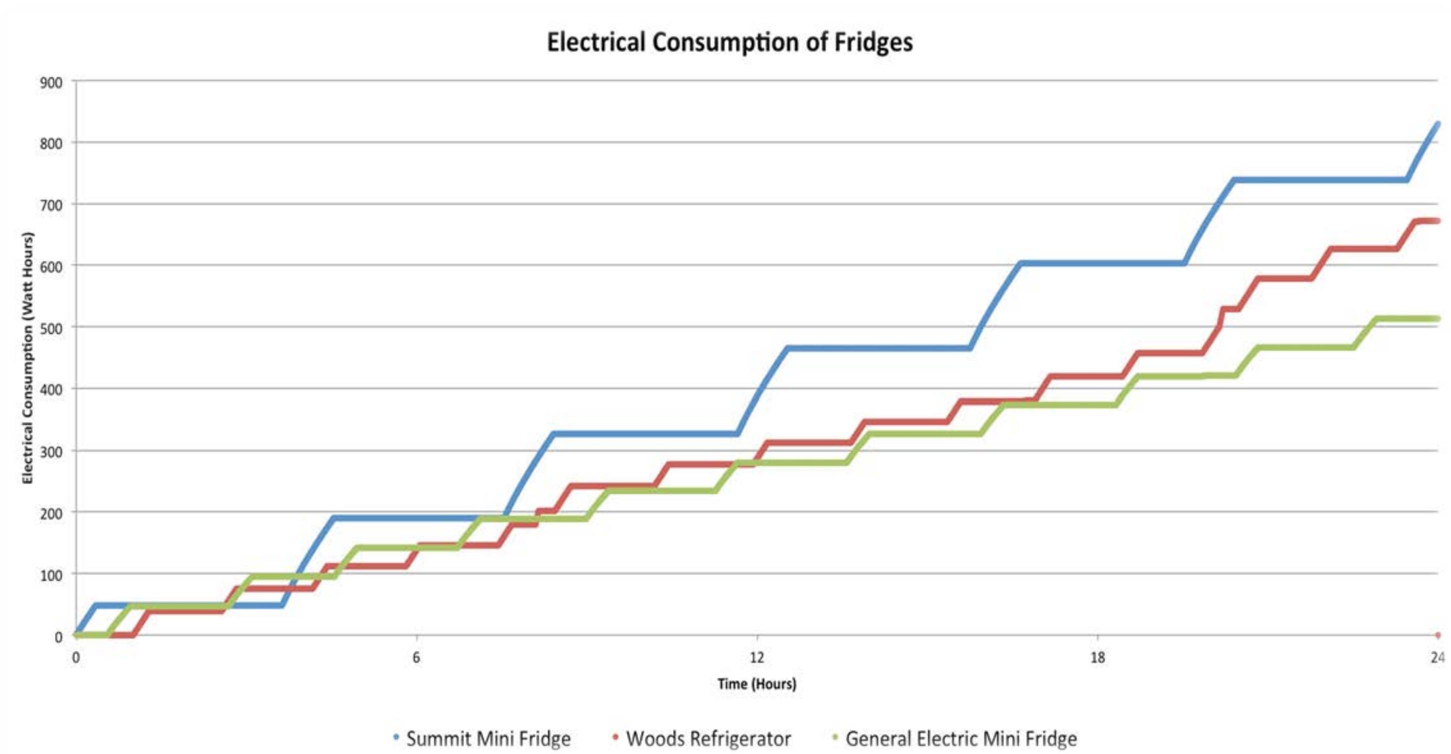

Figure 21: Electric Consumption of Refrigerators

It was determined that the Summit mini refrigerator consumed the most electricity, followed by the Woods refrigerator, followed by the General Electric mini refrigerator. An observation we made from these results is that the Summit refrigerator, although smaller, consumed more electricity than a standard size refrigerator. The Woods refrigerator not only provided more space for refrigerator use, but was also more energy efficient than the Summit mini refrigerator. When we tested the General Electric mini refrigerator, we found that it consumed significantly less energy than the originally tested Summit mini refrigerator, which consumed nearly twice as much energy. From the 24 hour electricity consumption we were able to calculate an approximation of the annual cost to power each model refrigerator. The Summit mini refrigerator consumes 14,782.5 kWh per year, the Woods refrigerator consumes 1,495.04 kWh per year and the General Electric mini refrigerator consumes 1,495.04 kWh per year.

Yearly Energy Consumption of Different Fridges and Brands

Summit mini refrigerator

$$0.900 kWh * 365\ days = 328.5 \frac{kWh}{yr}$$

$$328.5 \frac{kWh}{yr} * 45 = 14{,}782.5 \frac{kWh}{yr}$$

General Electric mini refrigerator

$$0.512\ kWh * 365\ days = 186.88\ kWh/yr$$

$$186.88 \frac{kWh}{yr} * 8 = 1{,}495.04\ kWh/yr$$

Woods refrigerator

$$0.671\ kWh * 365\ days = 244.9\ kWh/yr$$

$$244.9 \frac{kWh}{yr} * 2 = 489.8\ kWh/yr$$

4.4.2 Desktop Computer

We made energy measurements for a desktop computer at a sampling period of 10 seconds over 24 hours. The desktop computer we chose to use was located in one of the High School computer labs. This computer was used in a variety of ways throughout the day from running CAD software to browsing the Internet. The data collected indicated that the computer experiences heavy use during the day as it had consistently high watt readings. At about 6 pm, they are put into standby mode, causing the computers to draw a relatively low wattage of about 3 watts. The computers in the school are not powered down after school hours, due to automatic updates that run at night. Another observation we have made from the computer data is that the monitor is not turned off overnight. A computer monitor draws 10 watts when turned on, 5 watts when in standby (sleep) mode, and 0 watts when turned off. The data we collected from the computer shows that the monitor is not turned off, but rather falls into standby mode when inactive over periods of time.

4.4.3 Coffee Machines

When completing our inventory of the public school buildings, we found that many classrooms and common areas had coffee makers. They consisted of several brands of traditional coffee makers and newer Keurig brand coffee makers. Often times there were Keurig machines inside a classroom located directly next to a common area with the same appliance. Because coffee makers were prominent throughout the schools, we measured the electricity consumption of both a traditional Mr. Coffee Pot and Keurig machine. The two brands that we tested can be seen in Figure 22. Figure 23 shows the total Watt-hours used by both the Keurig and Mr. Coffee Pot over a 2 hour time period.

Figure 22: Keurig and Mr. Coffee Pot

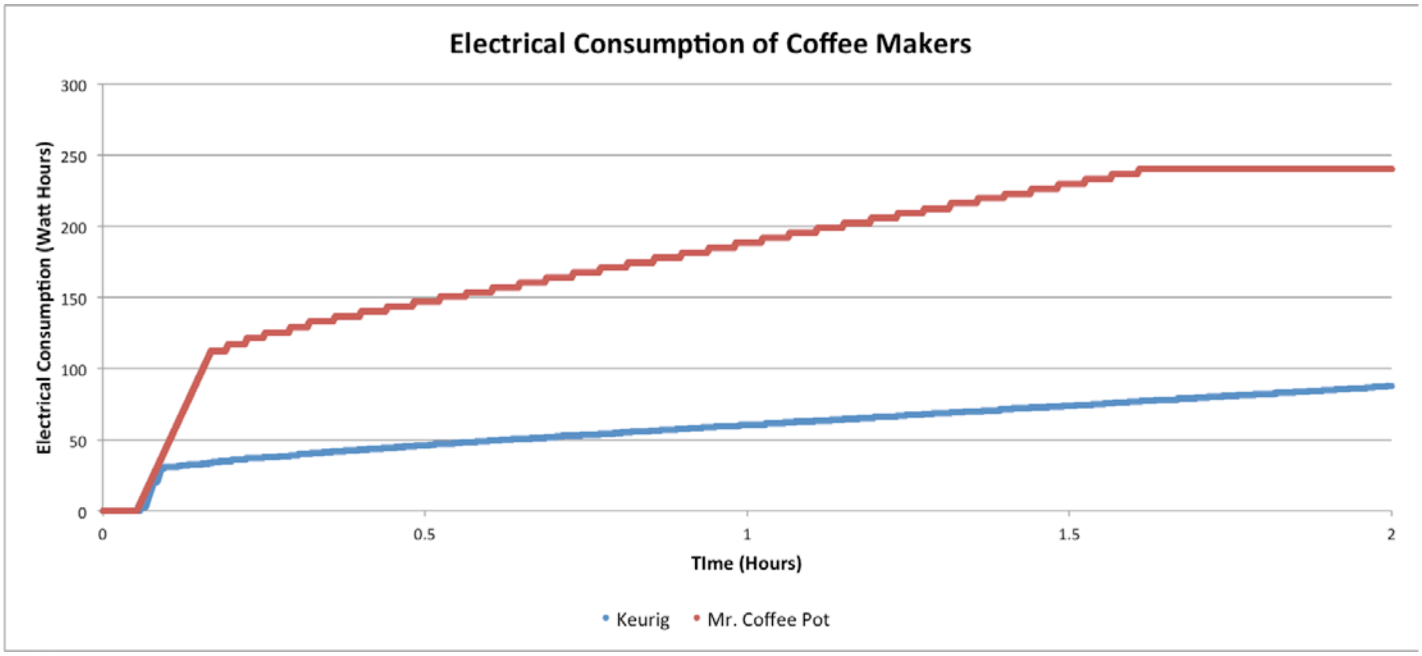

Figure 23: Keurig Watt-Hours

As the two coffee makers begin to brew coffee, the Mr. Coffee Pot consumes 60 Watt-hours more than the Keurig. Although Mr. Coffee Pot makes more cups of coffee in one use than a Keurig, Mr. Coffee consumes approximately 100 Watt-hours to keep the coffee warm where as the Keurig only uses 50 Watt-hours to power the Keurig coffee pot. The comparison of the two lines indicate that the Keurig consumes less total energy and is more energy efficient than a Mr. Coffee Pot. Although this setting was not enabled when collecting our data, most Keurig coffee makers have an automatic shut-off feature which reduces the amount of energy consumed by the appliance when not in use.

4.5 Structural Findings

As part of our technical assessment of the Nantucket Public Schools, we tested every room in each building with the tools introduced in section 2.6.3. We paid close attention to external windows, doors and walls to test the quality of insulation in the schools. We most frequently used the FLIR to find changes in temperature identifying leaks in heat in the buildings. We also put the FLIR to the test on the rooftops of each building. We did not collect any concerning data for the rooftops themselves, but we did identify several doors, windows and walls which appeared to be leaking heat.

In the elementary school, several doors that led outside experienced cold air leaking into the classrooms. Figure 24 shows a FLIR image of an exterior door in the kindergarten wing with surface temperatures ranging from 17 Celsius to 26 Celsius (62 Fahrenheit to 78.8 Fahrenheit). The areas of leaking are most prominent at the bottom of the door and at the hinge of the door. As we took thermal images of the door, the teacher of the classroom explained to us that during rainy weather, water leaks through the frame of the door and often forms small puddles in the classroom.

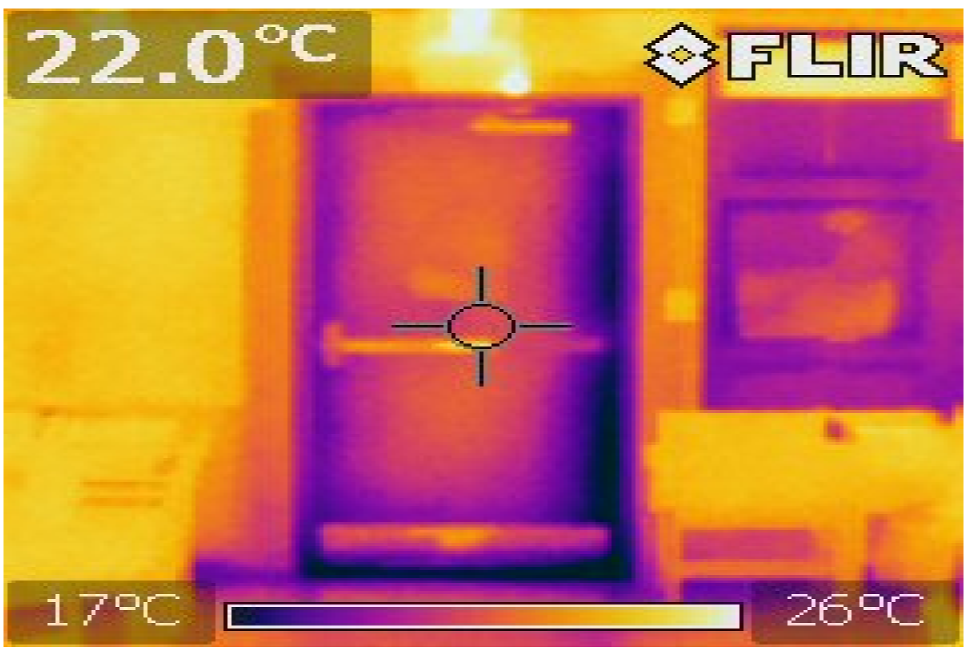

Figure 24: An Exterior Door in Nantucket Elementary School

An example of another inefficiency found within the walls of a Nantucket Elementary School classroom is shown in Figure 25. The image on the left is displaying the wall from inside the classroom facing out onto the roof and shows that the studs in the wall are warmer than the insulation that is between them. It is clear that the studs in the walls are absorbing heat and appears that cold air from outside is potentially leaking through the insulation of the walls. This indicates that the insulation in the walls can be improved. The image on the right is of the same wall but is taken of the exterior side taken from the roof. This image displays the same results as the image on the left where the studs are shown to be warmer than the insulation between them.

Figure 25: Internal and External FLIR Wall Photos

Many of the windows within all of Nantucket Public Schools are poorly insulated. Several photos were taken showing that heat is escaping through the window panes. Figure 26 shows an example of one of the many poorly insulated windows. The image displays one of the large windows within the main hallway of Nantucket High School. The image shows a potential 10 degree (Fahrenheit) between the surface temperature of the windows and the frame of the windows. This indicates that heat is escaping through the window's frame.

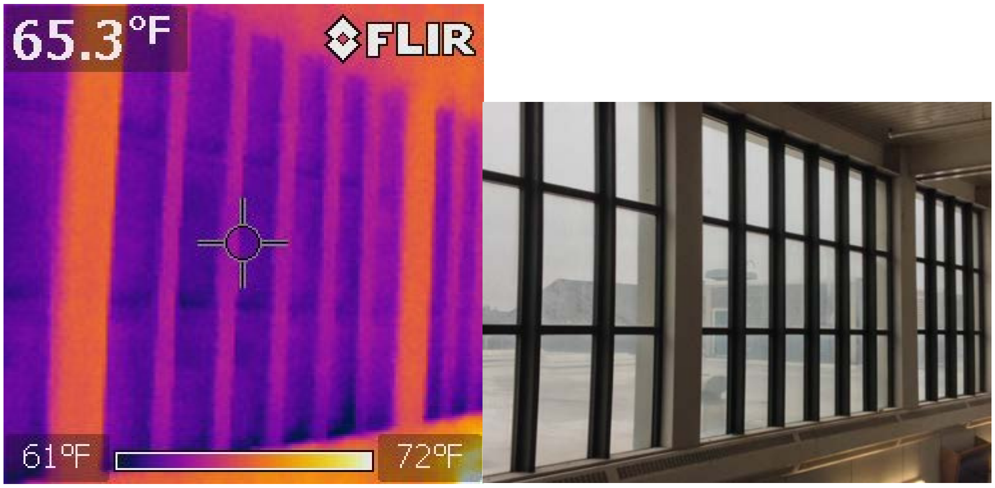

Figure 26: FLIR Images of Window in Main Corridor of NHS

4.6 Lights

Another finding we have made is that there are many locations in the schools which have lights turned on when there is sufficient natural lighting for the room/hallway. In the main corridor of Nantucket High School, a wall of lights that are located under the bay windows are always turned on during the day, despite the amount of natural light emitted from the bay windows. These lights are shown in Figure 27.

On a particularly cloudy day, we tested the lighting in the main corridor using the digital lux meter. We first measured the lux from the center of the hallway to be 320 lux, while the lights were turned on. We then turned the lights off and measured lux again, which yielded a reading of 220 lux. The U.S. federal standard for lighting a public hallway is 200 lux, which confirms our speculation that the hallway has sufficient natural light during the day.

Another observation we made regarding lighting is that lights are often left on in classrooms when there is no one in the classroom. When conducting inventory during after-school hours we often entered empty classrooms which had all of their lights switched on. This concept of conserving light electricity was frequently mentioned when conducting our teacher interviews. When asked to describe one thing they would change about how Nantucket Public Schools uses energy, many teachers answered with the response that lights could be turned off when not in use. Several teachers noted they often see well-lit, empty classrooms both during the day and after school.

Figure 27: Main Corridor Lights

4.7 Heating and Cooling Systems

Approximately 58% of the Nantucket Public Schools yearly energy costs consist of water, oil and gas bills. These three utilities are used to provide heat through the HVAC system and to the High School pool. Through our observations we noted that classrooms are often uncomfortably warm and had open windows which indicated that there is a problem with HVAC control and that energy is being wasted. Figure 28 shows the corner windows and radiator of a classroom within the elementary school. The heat is on and is flowing right out the window.

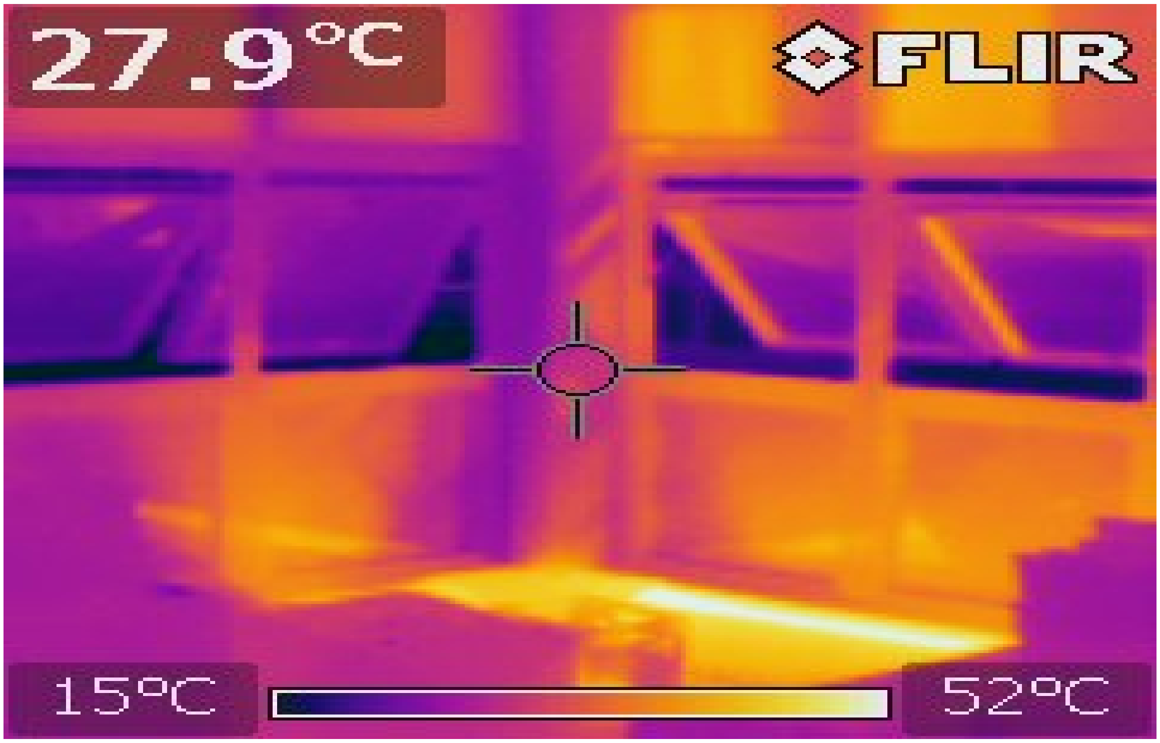

Figure 28: FLIR Image of NES Classroom Windows

Not only do rooms experience problems with heat control, but many receive little heat and are reach very cold temperatures. In our second survey to the Nantucket Public Schools staff, we posed the following question:

"During this time of the year, I find my classroom/office's temperature to be _____"

They were given five options to answer: cold, cool, comfortable, warm, or hot. Of the 102 responses, we found that 36% of the staff found their work area to be either "cool" or "cold". After conducting a classroom observation in a noticeably cold room, the teacher was interviewed on the matter. When we asked High School Biology teacher Heather MacDonald to describe the heating in her classroom, she noted that it experiences extreme temperatures. It is uncomfortably hot throughout most of the school year, but is very cold during the current winter season. The vents blow cool air which she refers to as "cold heat".

5.0 Recommendations and Conclusions

Overall, there are both behavioral and technical improvements that Nantucket Public Schools can implement to conserve energy. It is the ultimate decision of the Nantucket Public Schools whether or not to implement these recommendations.

Conclusion 1: Most of the staff is aware of the need for energy conservation and the different uses of energy in the Nantucket Schools

Recommendation 1: Implement the energy awareness website displayed in Figure 29 along with informational posters of associated QR codes linking to the website. Posters can be color coded by the different categories of energy facts. Categories include: Global energy facts, Nantucket energy facts, Nantucket Public Schools energy facts, and renewable energy facts. This websites can spread knowledge about energy conservation and energy consumption within the Nantucket Public Schools.

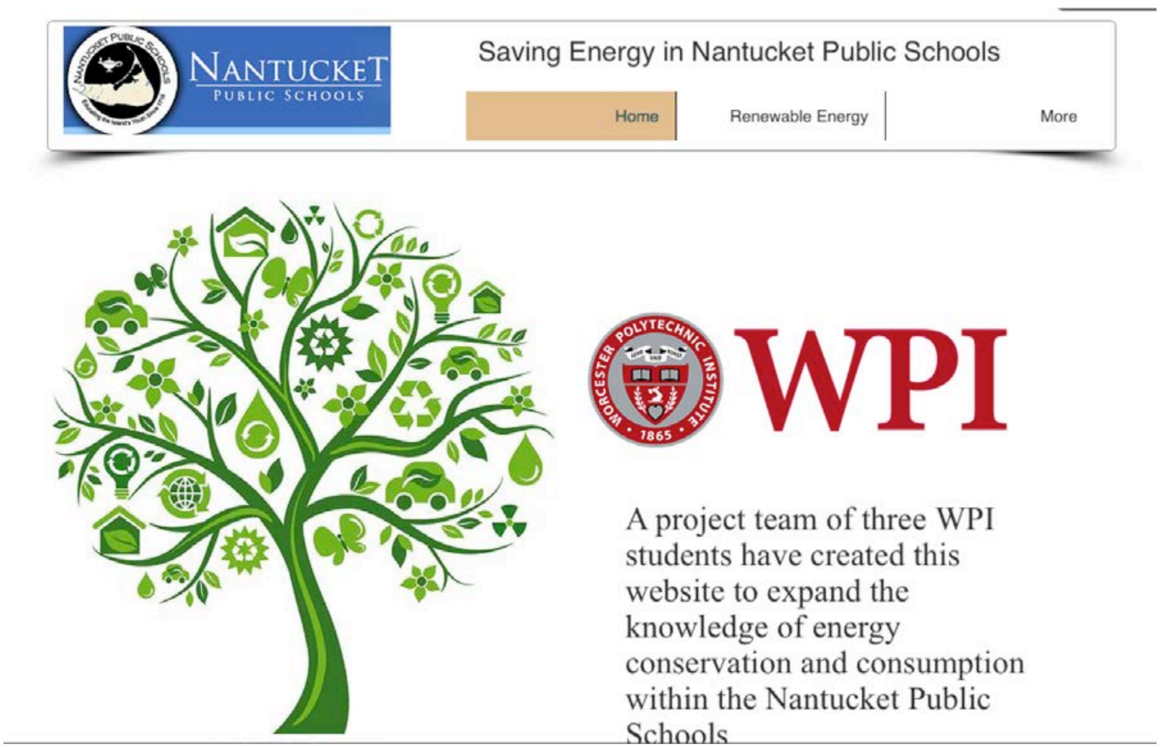

Figure 29: Home Page of Educational Website

The website is free and can be easily updated through wix.com. This website can lead to other energy awareness projects. The website contains general information about wind and solar energy resources, energy facts, and a fun section that has links to various videos and energy games that will increase energy conservation and energy consumption awareness.

Recommendation 2: Have energy efficiency awareness reminders around the school. Putting up posters and switch stickers to remind staff and students to turn off lights and to turn off computer monitors when not in use can help make significant reductions in energy consumption. Placing an energy kiosk at the main entrance of the high school could also be very beneficial. This recommendation will have a positive behavioral impact on how Nantucket Public Schools consumes energy.

Recommendation 3: Have an educational energy awareness assembly as a way for Nantucket Public Schools as a whole to work together to reduce energy consumption. It is the quickest way to get information about energy consumption and awareness to the faculty and students.

Recommendation 4: Create an energy club. This energy club can help run the educational energy website as well as the energy kiosk at the main entrance. There are several opportunities for the energy club to promote energy awareness within Nantucket Public Schools.

Recommendation 5: Integrate Energy educational resources into the curriculum. There are numerous resources for energy curriculum for every grade. Special websites such as need.org, Energy Information Administration: Energy for Kids, and the National Grid Energy Explorer all have certified curriculums ranging from calculating of how many watt-hours a device uses in 7 hours to simple student home audits projects to help reduce energy consumption. These resources are at no cost to the Nantucket Public Schools which makes them a great resource. The National Grid Energy Explorer, shown in Figure 30, is an interactive website for students and teachers that provides energy based web games. This website has content for students ranging from pre-k to 8th grade. These educational resources can be easily integrated in Nantucket Public Schools curriculum.

Figure 30: Energy Explorer Website

Conclusion 2: Numerous opportunities exist for improvements within the schools to conserve energy.

Recommendation 1: Invest in energy efficient windows. The current windows leak heat (as shown in section 4.5, Figure 26), in both classrooms and corridors. Applying to specific grants can help pay for these upgrades. There is currently a proposal to replace Nantucket High School windows in the main corridors; however replacing windows in classrooms will help increase thermal efficiency and conserve energy.

Recommendation 2: Re-Evaluate the placement of certain lights in hallways or invest in better motion light switches. In the Nantucket High School main corridor, there are a series of lights that are unnecessary. From a 7-week observation, the windows in the main corridor provide enough light throughout the day. By just those lights under the bay windows in the corridor, Nantucket Public Schools can save about $15 a year. By applying this to other critical areas, the savings in the schools will grow even larger. Upgrading and replacing broken motion light switches would help Nantucket Public Schools conserve energy by automatically shutting off lights when the room is not in use.

Recommendation 3: Install weather stripping around exterior doors. Replacing the current weather stripping will better insulate the building.

Recommendation 4: Have selected walls in Nantucket Elementary School re-insulated. From Figure 25 in section 4.5 there are several walls at Nantucket Elementary School that have little to no insulation and make the rooms thermally inefficient. It is recommended in the future that these walls be reinsulated so that there are minimal leaks through the walls.

Recommendation 5: Improve HVAC systems such as controlled thermostats. Masssave.org has an existing program that can upgrade the thermostats in only homes but further contact could lead to the creation of a new program and possibly even pair some agreement with National Grid.

Conclusion 3: Energy is wasted by old appliances and electrical devices.

Recommendation 1: Remove as many personal appliances as possible from offices and classrooms. Reducing the amount of personal appliances and then using more energy efficient shared appliances will help reduce the total amount of energy consumption throughout the Nantucket Public Schools. There are two scenarios for the recommendation.

Description	Cost	Calculation	Savings per Item	Pay Back Period	Total Savings after Payback Period
Scenario 1: If the 27 Mini Fridges within classrooms are removed this does not include clusters or offices	N/A	.815kWh/Day	$41.65/year	N/A	27 Fridges= $1,124.46/year
Scenario 2: In all there are 60 mini fridges; This suggests that 48 of them should be removed and 12 of them are upgraded to energy efficient communal fridges (excluding existing fridges in both elementary and middle school teacher lounges)	$400 per Fridge $4800 total	Removing 48 Old-> .815kWh/Day Upgrading 12 New->.720kWh/Day	Removal is $41.65/year per fridge. Upgrade saves $4.85/year per fridge	28 Months	$2057.40/year

Table 24: Cost Benefit Analysis Scenarios

Recommendation 2: Replace old appliances with Energy Star rated appliances. Upgrading these appliances will reduce the total energy consumption within the Nantucket Public Schools. Energy Star has provided a list of Energy STAR approved appliances on their website.

Recommendation 3: Apply for energy retrofit programs and grants. Many of these programs pay half the cost of the upgrades for a new heating system and new light bulbs. An example retrofit program is the SAPHIRE program and the Energy-Saver/Water-Reduction Devices Free Products Opportunity for State Agencies and Municipalities program. The SAPHIRE program focuses on heating systems and provides a grant for schools to upgrade to thermal efficient technologies. The Energy-Saver/Water-Reduction program replaces faucets with low flow water heads.

Recommendation 4: Invest in Smart Power strips. The Smart Power strips reduce energy usage by shutting off power to the outlets. As seen from table, integrating the Smart Power strips can save the schools can save on average 3,433.60 per year.

Description	Cost	Calculation	Savings per Item	Pay Back Period	Total Savings after Payback Period
These strips automatically turn off any device plugged in that's not in use after a period of time; Suggested devices to plug in: Monitors and Appliances. Assume at just one strip per room for analysis	$28.50 per 7 Plug Strip	Average 5W phantom load per device 35W x 12Hrs= 0.44kWh/Day per Room	$21.46/year per Room	16 Months	160 rooms= $3,433.60/year

Table 25: Cost Benefit Analysis of Smart Power Strips

Other Recommendations:

Recommendation 1: Continue to update the Energy Star Portfolio. This portfolio allows the school to continue to monitor their energy status and become certified as a green school which makes the schools eligible for possible grants and efficiency programs.

Recommendation 2: Implement blackout shades for the classrooms that are affected by the wind turbine flicker. From our survey, we have concluded that 17 rooms are affected in the elementary school by the wind turbine’s flicker. Allowing the wind turbine to run more regularly without stops will allow the schools to save more energy. Although a cost benefit analysis could not be done due to lack of information regarding wind turbine output per hour, the cost of the blackout shade for one window pane is $20 which is inexpensive compared to the potential savings.

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Appendix A: Inventory and Breakdown of Nantucket High School

High School Inventory		
Appliance/Device	**Quantity**	**kWh per Week**
Tube Lights	2704	2366
Desktop Computers	195	1073.016
Microwave	8	400.32
Laptops	33	338.184
Printer	21	186.48
Mini Fridge	19	108.528
Smart Board	23	104.88
Projector	9	31.5
Keurig	4	14.4
Fan	38	8.74
Coffee Maker	1	3.84
Lamp	12	3
Faucets	88	0

Appendix B: Inventory and Breakdown of Cyrus Pierce Middle School

Middle School Inventory		
Appliance/Device	**Quantity**	**kWh per Week**
Tube Lights	1676	1466.5
Desktop Computers	240	1306.2
Microwave	15	750.6
Laptops	33	338.184
Printer	23	204.24
Smart Board	20	91.2
Mini Fridge	11	62.832
Projector	17	59.5
Keurig	5	18
Coffee Maker	4	15.36
Lamp	22	5.5
Fan	19	4.37
Faucets	64	0

Appendix C: Inventory and Breakdown of Nantucket Elementary School

Elementary School Inventory		
Appliance/Device	**Quantity**	**kWh per Week**
Tube Lights	1320	1161.3
Desktop Computers	148	844.2
Laptops	79	809.592
Microwave	10	500.4
Mini Fridge	30	171.36
Smart Board	33	150.48
Projector	40	140
Printer	10	88.8
Keurig	7	25.2
Coffee Maker	3	11.52
Lamp	33	8.25
Fan	19	4.37
Faucets	132	0

Appendix D: Inventory and Breakdown of Nantucket Community School

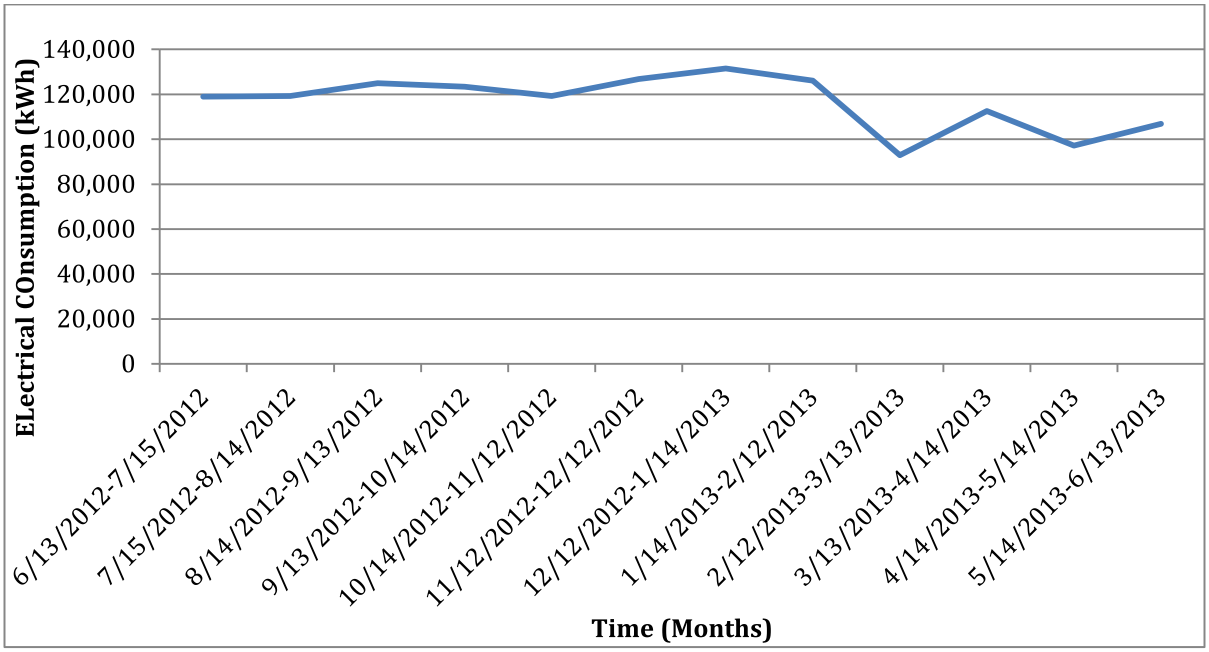
Community School Inventory		
Appliance/Device	**Quantity**	**kWh per Week**
Microwave	1	50.04
Laptops	3	30.744
Tube Lights	12	10.5
Printer	1	8.88
Mini Fridge	1	5.712
Keurig	1	3.6
Fan	3	0.72
Desktop Computers	0	0
Faucets	0	0
Projector	0	0
Smart Board	0	0
Lamp	0	0
Coffee Maker	0	0

Appendix E: Table of Energy Bills

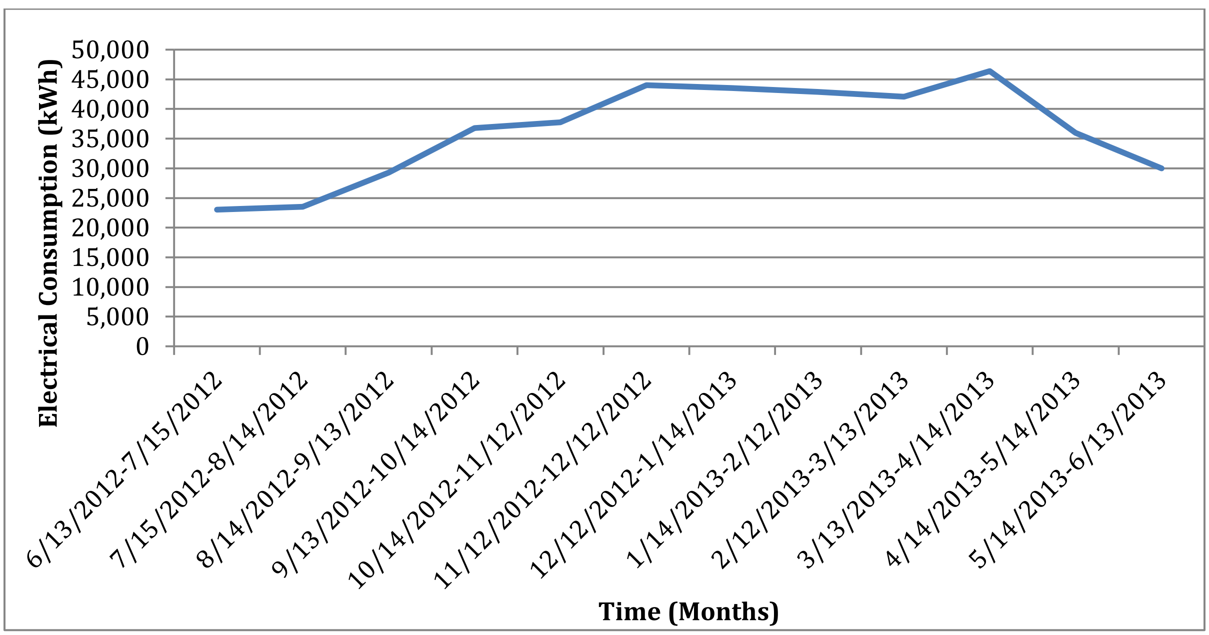
<table>
<tr><th colspan="7">Average Annual Energy Bills of Nantucket Publics Schools from 2010-2013</th></tr>
<tr><th>School</th><th>Oil Bill</th><th>Sewer Bill</th><th>Electricity Bill*</th><th>Water Bill</th><th>Gas Bill</th><th>Total School Bill</th></tr>
<tr><td>Nantucket Elementary School</td><td>$87,052.25</td><td>$8,222.16</td><td>$60,227.34</td><td>$6,259.43</td><td>$0.00</td><td>$161,761.18</td></tr>
<tr><td>Cyrus Pierce Middle School</td><td>$24,204.67</td><td>$3,448.79</td><td rowspan="2">$185,788.11</td><td>$2,691.75</td><td>$0.00</td><td rowspan="2">$475,635.48</td></tr>
<tr><td>Nantucket High School</td><td>$205,802.00</td><td>$12,760.73</td><td>$10,856.75</td><td>$30,082.68</td></tr>
<tr><td>Total Energy Bill</td><td>$317,058.92</td><td>$24,431.68</td><td>$246,015.45</td><td>$19,807.93</td><td>$30,082.68</td><td>$637,396.66</td></tr>
<tr><td>Percentage from Total Energy Bills</td><td>49.80%</td><td>3.80%</td><td>38.60%</td><td>3.10%</td><td>4.70%</td><td>100%</td></tr>
</table>

***Average calculation was done using 2012-2013 energy bills**

Appendix F: High School and Middle School Electrical Consumption Chart



Appendix G: Elementary School Electrical Consumption Chart



Appendix H: Cost Benefit Analysis

Cost Benefit Analysis						
Reccomendation	**Description**	**Cost**	**Calculation**	**Savings per Item**	**Pay Back Period**	**Total Savings after Payback Period**
Lights in Main Hallway under Whale can be turned off during the day	This room is often very bright throughout the day, and the lights being on has no difference in the lighting.	N/A	25W x 12Hrs= 0.3kWh/Day	$15.33/year	N/A	$15.33/year
Smart Power Strips	These strips automatically turn off any device plugged in that's not in use after a period of time; Suggested devices to plug in: Monitors and Appliances. Assume at just one strip per room for analysis	$28.50 per 7 Plug Strip	Average 5W phantom load per device 35W x 12Hrs= 0.44kWh/Day per Room	$21.46/year per Room	16 Months	160 rooms= $3,433.60/year
Removal of Personal Mini Fridges	**Scenario 1:** If the 27 Mini Fridges within classrooms are removed this does not include clusters or offices	N/A	.815kWh/Day	$41.65/year	N/A	27 Fridges= $1,124.46/year
	Scenario 2: In all there are 60 mini fridges; This suggests that 48 of them should be removed and 12 of them are upgraded to energy efficient communal fridges (excluding existing fridges in both elementary and middle school teacher lounges)	$400 per Fridge $4800 total	Removing 48 Old-> .815kWh/Day Upgrading 12 New->.720kWh/Day	Removal is $41.65/year per fridge. Upgrade saves $4.85/year per fridge	28 Months	$2057.40/year
Black Out Shades-Wind Turbine Flicker	To optimize wind turbine output, we are suggesting teachers that have issues with flickering from the wind turbine to have blackout shades for the 3 hour duration of the flicker	$19 per curtain	6kW/hr x 3hr of Flickering = 18kWh/day of potential generation	$655.20/year assuming flickering is only an issue 5 days of the week for 52 weeks in a year	Depends on # of curtains	$655.20/year in Renewable Energy Credits

Appendix I: First Survey

WPI

What grade(s) do you teach? If you are not a teacher, select "other". If you do not wish to answer this question please select "Do not wish to specify". (You may choose more than one answer).

- ☐ Pre-K
- ☐ Kindergarten
- ☐ 1st grade
- ☐ 2nd Grade
- ☐ 3rd Grade
- ☐ 4th Grade
- ☐ 5th Grade
- ☐ 6th Grade
- ☐ 7th Grade
- ☐ 8th Grade
- ☐ 9th Grade
- ☐ 10th Grade
- ☐ 11th Grade
- ☐ 12th Grade
- ☐ Other
- ☐ Do not wish to specify

What is your current position and about how long have you held that position?

Which building do you spend most of your time working in?

- ○ Nantucket Elementary School
- ○ Cyprus Middle School
- ○ Nantucket High School
- ○ Community School

For each of the following statements, please select the answer that best describes your personal energy use in school buildings.

	Never	Rarely	Sometimes	Often	Always
I turn off the lights when I leave a room.	○	○	○	○	○
I use natural light in the classroom or office in place of artificial lighting.	○	○	○	○	○
I turn off computers when not in use.	○	○	○	○	○
I turn off computer monitors when not in use.	○	○	○	○	○
I turn off projectors when not in use.	○	○	○	○	○
I unplug chargers and other small electronic devices when not in use.	○	○	○	○	○

For each of the following questions, please make a selection within the range that best represents your opinion.

	Never	Rarely	Sometimes	Often	Always
Conserving energy in Nantucket Public Schools is not very important to me; I don't pay the bills so why should I care?	◯	◯	◯	◯	◯
I have little control over the amount of energy used in this facility, so even if I tried to conserve energy it wouldn't make a difference.	◯	◯	◯	◯	◯
Energy Conservation is an important issue these days so people should try to do everything they can at home and in the schools to save energy.	◯	◯	◯	◯	◯
If I tried to conserve energy I'd have to give up certain comforts and conveniences and I don't want to do that.	◯	◯	◯	◯	◯

What do you believe consumes the most amount of energy during your daily school routine?

In what ways do you believe you contribute to energy conservation in Nantucket Public School buildings?

What conscious efforts do you make daily to conserve energy?

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Appendix J: Second Survey

Please answer the following questions to the best of your ability, being as honest as possible. This survey is anonymous and should take no longer than 5-10 minutes.

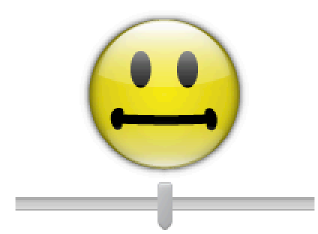
For each of the following statement, please make a selection within the range that best represents your opinion.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Conserving energy in Nantucket Public Schools is not very important to me; I don't pay the bills so why should I care?					
I have little control over the amount of energy used in this facility, so even if I tried to conserve energy it wouldn't make a difference.					
Energy Conservation is an important issue these days so people should try to do everything they can at home and in the schools to save energy.					
If I tried to conserve energy I'd have to give up certain comforts and conveniences and I don't want to do that.					

Please check all the following appliances that are in your office, classroom or workplace. If there are any others not listed below that you can think of, please select other and write in your answer.

- Keurig
- Coffee maker
- Mini Fridge
- Microwave
- Hot Water maker
- Toaster
- Smartboard
- Other

Please use the sliding scale to indicate how you feel about removing personal appliances from classrooms and replacing them with common appliances in common areas and teachers' lounges (The left most face being extremely discontent, the middle face being indifferent, and the right most face being extremely content).



Please select the answer for each of the following statements that best represents your personal opinion. (Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree)

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Current energy initiatives are visible and recognizable	◯	◯	◯	◯	◯
I feel I have been adequately educated on how to effectively conserve energy.	◯	◯	◯	◯	◯
I am interested in participating in energy conservation projects for Nantucket Public Schools and for the community of Nantucket.	◯	◯	◯	◯	◯
I would like to see more visible reminders about energy consumption and energy conservation tips.	◯	◯	◯	◯	◯

Do you use surge protectors to power multiple electronic devices?

How often do you use your smart board? If you do not have a smart board in your classroom or office space, please select N/A.

- ◯ Everyday
- ◯ 2-4 times per week
- ◯ Once per week
- ◯ 2-3 times per month
- ◯ Once per month
- ◯ Never
- ◯ N/A

If you have a SMART Board in your classroom, describe how you use the applications in your teaching. If you do not have a SMART Board, please type the response "N/A" (i.e. I write on the smart board to show students how to solve a math problem. I use the smart board create notes that I can hand out to students).

Does your classroom or office experience any kind of outside disturbance from the wind turbine, such as light flickering or noise? If you select "Yes", please elaborate.

- ◯ No
- ◯ Yes

During this time of the year, I find my classroom/office's temperature to be __________.

- Cold
- Cool
- Comfortable
- Warm
- Hot

Which of the following best describes an action you normally take when you find your classroom/office to be too warm?

- Open a window
- Remove a layer of clothing
- Contact the facilities department
- Nothing
- Other

Which of the following best describes an action you normally take when you find your classroom/office to be too cold?

- Add a layer of clothing
- Contact the facilities department
- Nothing
- Other

At what temperature is your thermostat at home typically set to? (°F)

How likely are you to integrate energy consumption awareness and energy conservation topics into your curriculum if given the materials and resources? If you do not teach please select N/A.

- Very Unlikely
- Unlikely
- Somewhat Unlikely
- Unsure
- Somewhat Likely
- Likely
- Very Likely
- N/A

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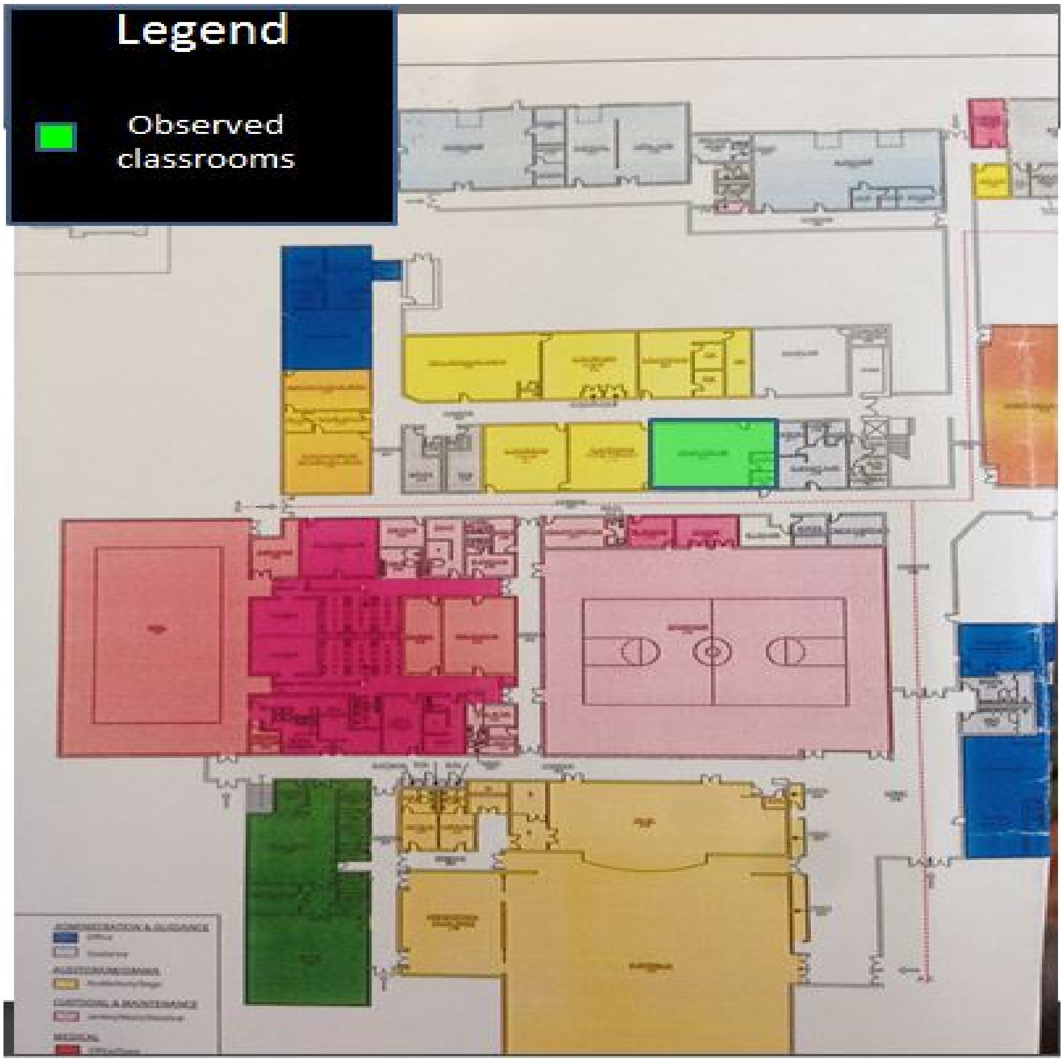
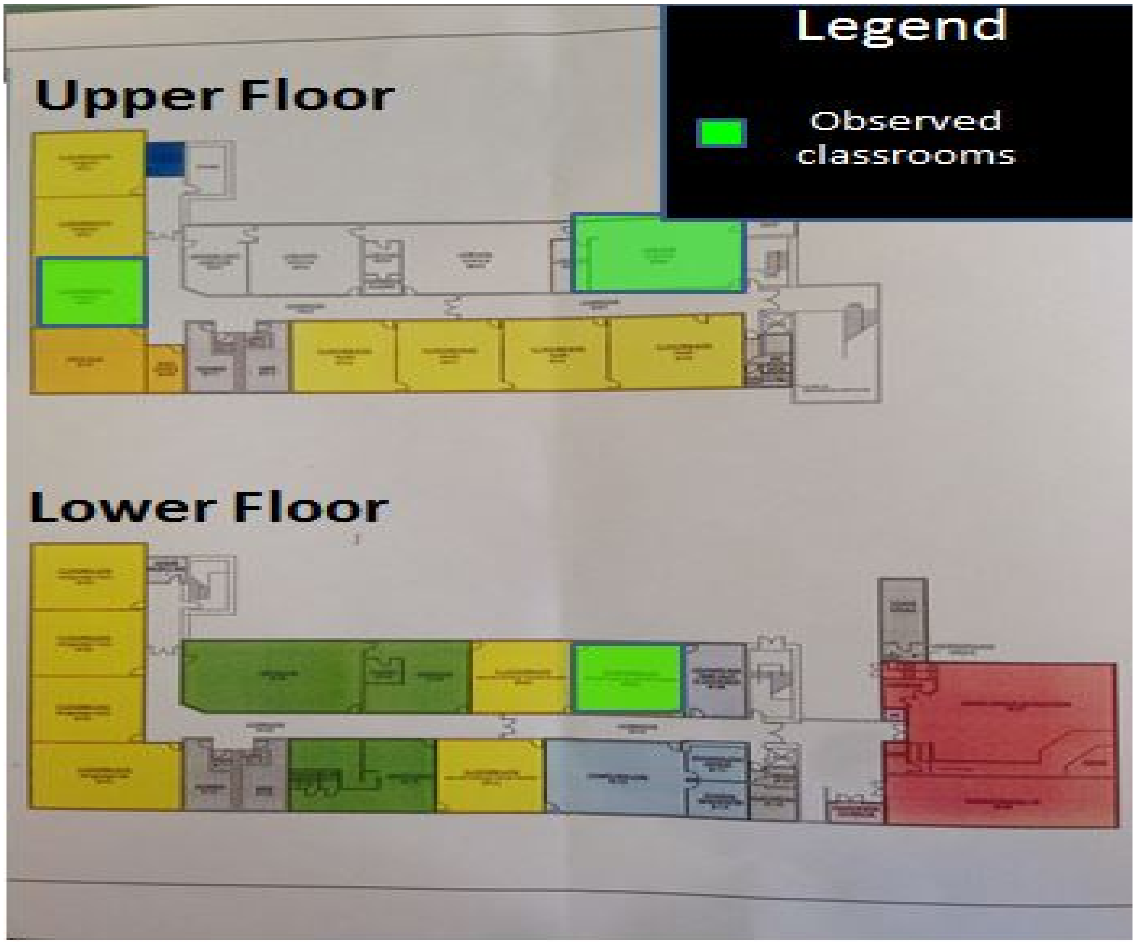
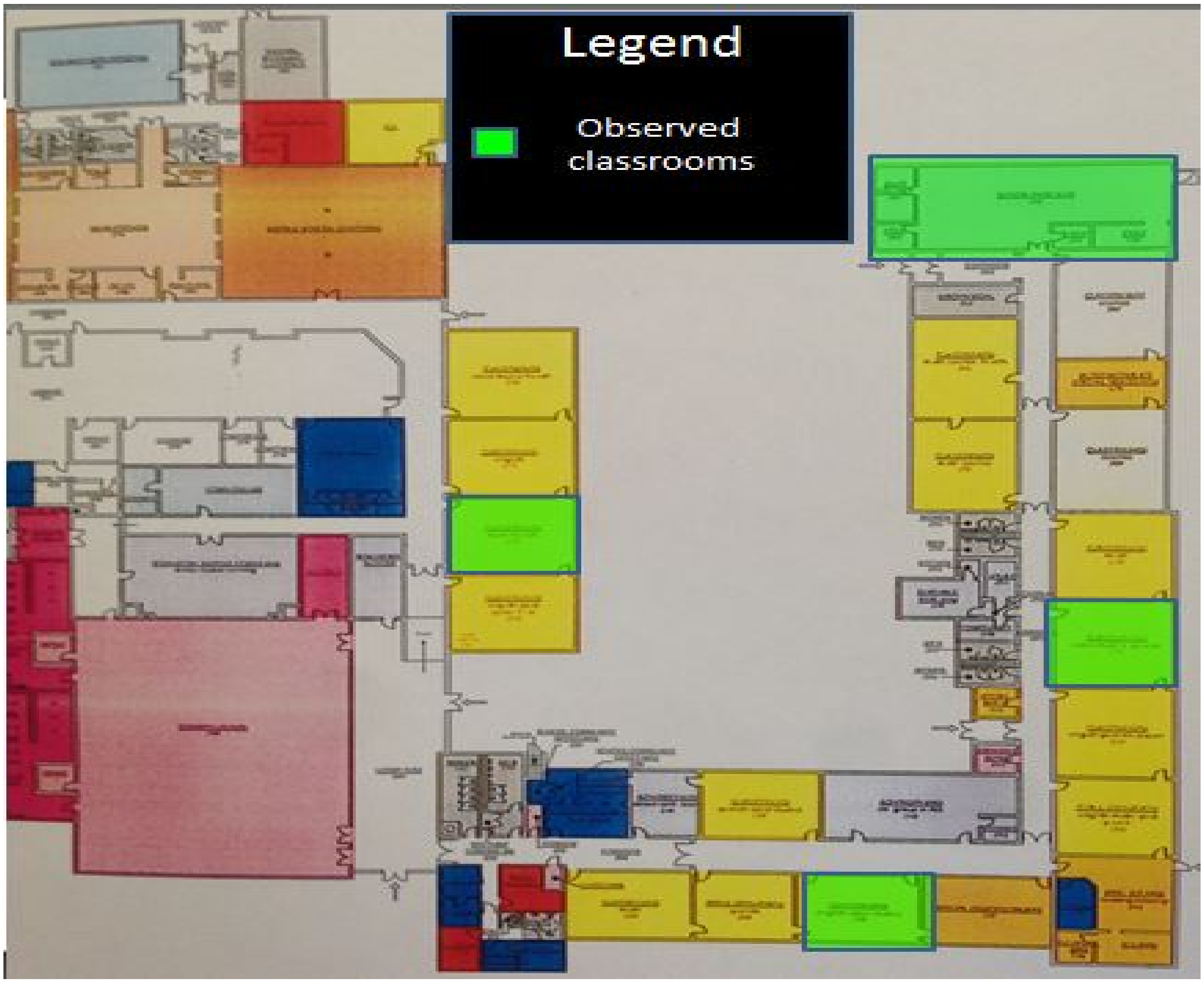
Appendix K: Map of Nantucket High School




Legend
Observed classrooms
Upper Floor
Lower Floor

Appendix L: Map of Cyrus Pierce Middle School



Appendix M: Map of Nantucket Elementary School

Appendix N: Classroom Observation Template

Classroom: ________________

Grade: ____________________

Subject: __________________

Heating Notes:

Lighting Notes:

Computer Usage Notes:

Is the Smart Board being used?: ______________

Appendix O: Teacher Interview Template

Teacher Interview Question

Classroom: ______________________

Grade: ____________________________

Subject: __________________________

1. What specific ways do you use energy during class time? What personal efforts do you make to conserve energy in the schools?

2. Can you briefly describe energy use in Nantucket Public Schools? How do you feel about how Nantucket Public Schools uses energy?

3. Based on your answer to the previous question, what is one thing you would change about energy use in Nantucket Public Schools in order to conserve energy.

4. How would you describe the heating in this classroom? Do you notice it being too warm, too cold or comfortable?

5. Do we have your consent to use the information we have gathered through observations and your answer to these interview questions in our final report?